APPLICATION OF PRICE UNCERTAINTY QUANTIFICATION MODELS AND THEIR IMPACTS ON PROJECT EVALUATIONS

A Thesis

by

FESTUS LEKAN FARIYIBI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2006

Major Subject: Petroleum Engineering

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Approved by:

Chair of Committee:	Duane A. McVay
Committee Members:	William J. Lee
	Wayne M. Ahr
Head of Department:	Stephen A. Holditch

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ABSTRACT

Application of Price Uncertainty Quantification Models
and Their Impacts on Project Evaluations. (August 2006)
Festus Lekan Fariyibi,
B.Sc., University of Ibadan, Nigeria;
M.Eng., University of Port-Harcourt, Nigeria
Chair of Advisory Committee: Dr. Duane A. McVay

This study presents an analysis of several recently published methods for quantifying the uncertainty in economic evaluations due to uncertainty in future oil prices. Conventional price forecasting methods used in the industry typically underestimate the range of uncertainty in oil and gas price forecasts. These forecasts traditionally consider pessimistic, most-likely, and optimistic cases in an attempt to quantify economic uncertainty.

The recently developed alternative methods have their unique strengths as well as weaknesses that may affect their applicability in particular situations. While stochastic methods can improve the assessment of price uncertainty they can also be tedious to implement. The inverted hockey stick method is found to be an easily applied alternative to the stochastic methods. However, the primary basis for validating this method has been found to be unreliable. In this study, a consistent and reliable validation of uncertainty estimates predicted by the inverted hockey stick method is presented. Verifying the reliability of this model will ensure reliable quantification of economic uncertainty.

Although we cannot eliminate uncertainty from investment evaluations, we can better quantify the uncertainty by accurately predicting the volatility in future oil and gas prices. Reliably quantifying economic uncertainty will enable operators to make better decisions and allocate their capital with increased efficiency.

DEDICATION

To my late parents, Isaiah S. and Abeke Fariyibi, who were always at my side in my endeavors before their demise.

To my wife, Omolola Victoria Fariyibi, for her undying love and always believing in me.

Finally, to my wonderful children, Ruth Anuoluwapo, Mary Ebunoluwa and Michael Olatunbosun, for being a source of inspiration to me throughout my graduate program.

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I want to first thank the Almighty God for His unseen hand that guides.

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I would also like to thank the Head of Department and Graduate Office staff of the Harold Vance Department of Petroleum Engineering, Texas A&M University, for their outstanding work throughout the duration of my graduate study.

Finally, I thank Chevron Nigeria Limited for sponsoring my graduate program.

NOMENCLATURE

BS	=	Bootstrap
CEC	=	California Energy Commission, (Conventional Hockey)
CMPC	=	Cumulative Monthly Price Change
CPI	=	Consumer Price Index
F_p	=	Future Cash Flows
HIST	=	Historical
IHS	=	Inverted Hockey Stick
IRR	=	Internal Rate of Return
j	=	Month of the Cash Flow
MPC	=	Monthly Price Change
n	=	Number of Periods
NPV	=	Net Present Value
NPVI	=	Investment Efficiency, ratio of net present value to the present value of the total investment
OPEC	=	Organization of Petroleum Exporting Countries
P	=	Monthly average price
$P_{ceiling}$	=	Price Ceiling
$P_{current}$	=	Current Price
P_{floor}	=	Price Floor
P_{min}	=	Minimum Historical Price
P_{max}	=	Maximum Historical Price
r	=	Discount Rate, fraction
SGS	=	Sequential Gaussian Simulation
V_{np}	=	Net Present Value
V_{pi}	=	Present Value of Investment

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CHAPTER I

INTRODUCTION

Oil and gas investments decisions throughout the life of a reservoir are made under significant uncertainty and risk. Quantifying uncertainty allows companies to better evaluate the risks associated with individual projects and, at the portfolio level, to make the best choices from an array of uncertain investment opportunities.[1] Today the petroleum industry is operating in an ever-changing technical, economical, and political environment.[2,3] Mian[2] stated that factors affecting decision making include technology advancements, new products and techniques, uncertainty of oil and gas prices, operating costs, equipment costs, inflation, market conditions, political risks, environment threats, reliability of aging production facilities, capital availability constraints, scarcity of good prospects and government regulations.

Economic uncertainty affects investments within the petroleum industry at least as much as technical uncertainty.[4] Unlike technical uncertainty, which should decrease with production of a reservoir, economic uncertainty does not decrease over the life of a petroleum reservoir. Future oil and gas prices represent a substantial source of economic uncertainty for operators considering exploration and development opportunities. Campbell *et al.* [5] affirmed that errors in project evaluations are more attributable to price forecasts than to any other component. Although we cannot eliminate uncertainty from investment evaluations, we can better quantify the uncertainty by accurately predicting the volatility in future oil and gas prices. Reliably quantifying economic uncertainty will enable operators to make better decisions and allocate their capital with increased efficiency.

Conventional forecasting methods commonly used in the industry typically under estimate the range of uncertainty in oil and gas price forecasts. These forecasts traditionally consider pessimistic, most-likely, and optimistic cases in an attempt to

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This thesis follows the style of SPE Reservoir Evaluation & Engineering.

quantify economic uncertainty. These price projections are commonly referred to as "hockey stick"[6] forecasts. Hockey stick price forecasts are initially flat or declining for some period of time and then increasing monotonically. Economic indicators calculated with such forecasts will not reliably quantify investment.

A number of additional references illustrate the tendency of individuals, industry and governmental organizations to underestimate uncertainty in future prices. In 2002, Mian[7] assumed that oil prices would stabilize between $18 and $30 per barrel for the coming decade. Since then oil price has been on a continuous increase. It rose to $48.47/bbl and $59.43/bbl in December 2004 and December 2005, respectively.[8] The price is expected to averaged $68/bbl in 2006. Caldwell and Heather[9] have declared that nearly all conventional price forecasts are "wrong 100% of the time" and "nobody believe[s] the forecasts anyway."

In an attempt to better quantify economic uncertainty resulting from future oil price variability, McMichael[6] presented the stochastic bootstrap method. However, this method can result in some realizations that exceed realistic price limits. Holmes, Mendjoge, and McVay[10] used sequential Gaussian simulation to arrive at equiprobable forecasts that honor the distribution and variability of historical prices. They also proposed a probabilistic forecasting model using realizations from historical price data. But, the historical method is only approximate because realizations are not equiprobable and can possess discontinuities at time zero of the forecast. While stochastic methods can improve the assessment of price uncertainty, they can also be tedious to implement. Akilu, McVay, and Lee[11] recently proposed the inverted hockey stick method as an easily applied alternative to stochastic methods. Their motivation was to develop a method that captures the uncertainty predicted by stochastic methods, but with the ease of calculation of the conventional hockey stick method. The IHS method serves as a reasonable approximation, and can easily be incorporated into existing procedures and software.

Review of the recently developed alternative methods shows that each of them have their unique strengths and weaknesses that may affect their applicability in particular situations.[12] These weaknesses present several questions that require further investigation. Most of the methods were initially tested with only three synthetic production scenarios. Olsen *et al.*[12,13] extended the techniques by applying them to a number of actual or proposed industry projects. He based the analyses on December 2002 historical oil and gas prices when the prevailing oil price was at $29.46/bbl. Since then the price of oil has risen to a record high doubling the 2002 price at $59.43/bbl in December 2005.

The overall question addressed in this research is whether further investigations on the applicability of these methods with sustained prevailing high prices will validate previous conclusions and confirm the relative advantages of recently developed methods over the conventional methods.

In this study, we present a consistent and more reliable validation procedure that will improve the inverted hockey stick (IHS) method for quantifying oil price uncertainty. We contrasted the bootstrap (BS) method with the sequential Gaussian simulation (SGS) method. BS and SGS methods are both stochastic in nature by providing multiple realizations and full distributions of results. In the previous work,[11] IHS forecasts were calibrated against the BS method on the assumption that it was more accurate in quantifying price uncertainty. Investigations in this research show that this assumption may not be valid. The major weaknesses of the conventional bootstrap method are that it does not preserve the correlation of prices in time and the predicted prices may drastically exceed historical extremes, resulting in unrealistic results. In addition, the range of prices in the forecast is very sensitive to the starting price. From a technical standpoint, SGS should be the better benchmark because it honors the distribution and variability of historical prices. The SGS method is the most rigorous and accurate method.[12] In this study, the IHS method was calibrated to the SGS method. The purpose is to obtain a more consistent and reliable method than the previous approach.

We investigated the probability distribution of SGS forecasts to determine the form of distribution. This distribution form was then used to calculate the IHS P50 or mean.

The overall goals of this study are to:

1. Determine the relative advantages of the four alternative forecasting techniques over the conventional method in estimating the range of uncertainty in oil price forecasts.
2. Evaluate the range of uncertainty in project economic indicators resulting from the uncertainty in oil price forecasts as predicted by various methods.
3. Develop a consistent and more reliable validation procedure for quantifying oil price uncertainty predicted by the inverted hockey stick method.

CHAPTER II

LITERATURE REVIEW

2.1 Oil and Gas Price Volatility

Perhaps no industry has witnessed a more cyclical activity than the petroleum industry.[8,14] Oil and natural gas account for a substantial part, over 70 percent, of world energy demand and utilization besides the worldwide application of its by-products. It is the main source of foreign exchange earning for many developing economies. Half a decade ago, crude oil price volatility made decision-making and strategic planning extremely difficult for companies. The oil companies responded to the low oil prices at the time by reducing research and development budgets, capital spending, and employment. The operators were cautious in capital spending and expansion. The consequences of price instability led to mergers and acquisitions, and internal re-organization in order to maximize profit. Today, oil prices are at their record high and the story is completely different.

Trends in energy supply and demand are affected by a large number of factors that are difficult to predict. Since 2000, world oil prices have risen sharply as supply has tightened. A review of a 5-year OPEC oil price data from January 2001 to May 2006,[15] as illustrated in **Fig. A-1** (Appendix A), gives some insights into the trend of oil price in the last five years. At its March 2000 meeting, OPEC set up a price band mechanism, triggered by the OPEC basket price, to respond to changes in world oil market conditions. According to the price band mechanism, OPEC basket prices above $28 per barrel for 20 consecutive trading days or below $22 per barrel for 10 consecutive trading days would result in production adjustments. This adjustment was originally automatic, but OPEC members changed this so that they could fine-tune production adjustments at their discretion. From late 2003, the price has been on the continuous increase. At its January 30, 2005 meeting, OPEC decided that market changes had rendered the band unrealistic, and decided to temporarily suspend the price band mechanism. Price of crude oil rose to record highs in 2005 largely due to enormous energy demands of China, other Asian Countries and United States. On May 2, 2006, the OPEC basket price rose to $64.80 per barrel, its highest price since the price band mechanism was established. From December 2, 2003, when the basket price last crossed the $28 per barrel threshold, the OPEC basket price has traded above the $28 per barrel level for 628 consecutive trading days through May 8, 2006.

Like anything else, when demand is high and supply is tight, prices rise. Other factors affecting price volatility include advances in technologies, changes in weather patterns and future public policy decisions. Continued steady world oil demand growth, combined with only modest increases in world spare oil production capacity and the continuing risks of political instability in several oil producing countries, are expected to keep crude oil prices high through 2006. In a recently published short term energy outlook by the Energy Information Administration (EIA),[16] the price of West Texas Intermediate (WTI) crude oil is projected to average $68 per barrel in both 2006 and 2007.

2.2 Uncertainty in Petroleum Project Evaluations

The literature indicates an informal distinction between “risk” and “uncertainty”,[3,17] although they have often been used as synonyms. The term “risk” is associated with the probability of total loss, while “uncertainty” is associated with the description of the range of possible outcomes. Caldwell and Heather[17] documented sources of uncertainty as including; measurement inaccuracy, computational approximation, the effect of incomplete data, and dealing with naturally stochastic systems. Garb[3] classified uncertainty in oil and gas producing assets into 3 groups: (1) technical, (2) economic and (3) political uncertainties. Technical uncertainty relates to whether or not the hydrocarbon volume estimated by geologists and engineers exists in the ground and whether or not the reserves and recovery rates will be as projected by the engineers. Political uncertainty includes local and national taxes, environmental regulations, operational restriction and political instabilities, as currently being experienced across the globe. Economic uncertainty deals with lack of knowledge of future oil and gas prices, drilling and production costs, and other parameters affecting the economic performance of petroleum assets.

A typical capital investment project evaluation requires input variables such as future product prices, production forecasted over the economic life of the project, initial capital expenditure and ongoing operating expenditures, useful lifetime of facilities, salvage value at the end of the economic life of the project, and interest rates.[2] Uncertainty is associated with most of variables in varying degrees. The uncertainty of some of the variables may be detrimental to the profitability of the investment as compared to others. Quantifying that uncertainty with ranges of possible values and associated probabilities will help everyone understand the risks involved. According to Brashear *et al.,*[18] the E&P industry has averaged 7% return on net assets during the 1980's and 1990's, despite massive improvements in productivity due to technology advances. These relatively low returns on investments may be partially due to oil and gas price forecasts that failed to recognize the true uncertainty in future price paths.

2.3 Management of Uncertainty

Caldwell *et al.*[9], while drawing attention to the problems posed by volatile pricing on reserves evaluations, remarked that the nature of prices defies a definite trend line or numerical correlation of any predictive significance. Research shows that people are not good at predicting future returns and simple extrapolation of historical returns has been a poor predictor of future returns.[19] Managing uncertainty is difficult at best. The most popular statistical forecasting tool is linear regression, which assumes that the past is linked to the future along a straight line fitted to a series of past outcomes. Linear regression is a notoriously poor way to predict future oil and gas prices. This approach is unable to capture the uncertainty in future prices. At each point in time there is a whole distribution of returns that could have occurred, rather than a linear trend.

Mian[2] highlighted many approaches that are being used in the industry, with varying degrees of sophistication, for treating uncertainty in capital investment decisions. The approaches include sensitivity analysis, scenario analysis, probability approaches and computer simulation. The simulation approach to project evaluation, which is known today as risk analysis, was originally developed by Herz[20] in 1964 in an article that has since become a *Harvard Business Review* reprint classic. Holmes *et al.*[10] also listed the methods that researchers followed to quantify the economic uncertainties as including Monte Carlo simulation, value at risk, bootstrap and fuzzy logic techniques.

Monte Carlo simulation is the most commonly used method in the industry, especially by the major oil and gas corporations. Murtha[21] described a Monte Carlo (MC) simulation as the process of creating a few thousand realizations of a model by simultaneously sampling values from the input distributions. The results of such an MC simulation typically include three items; a distribution for each designated output, a sensitivity chart listing the key variables ranked by their correlation with a targeted output, and various graphs and statistical summaries featuring the outputs. The value at risk, or V@R, technique is an extension of Monte Carlo simulation. V@R is defined in finance as the maximum loss that an institution can be confident it would suffer in a certain time within a particular period.

The bootstrap technique is also a type of Monte Carlos simulation, requiring a method of generating a sample set that are random, in some sense, with replacement. Each successive number in a sequence of random numbers must have an equal probability of taking on any one of the possible values. In addition, each number must be statistically independent of the other numbers in the sequence. In the case of this study, these bootstrap samples represent the daily fluctuations in crude oil prices.[6]

CHAPTER III

METHODOLOGY

3.1 Project Evaluation Workflow

In order to investigate the impacts of the price uncertainty quantification models on the project evaluations a workflow program was developed **(Fig. 3.1)** to consolidate five price forecasting models and execute the resulting economic evaluations. This is to minimize the discrepancies between the methods and the project cases. The workflow consists of three main components, namely price models, economic model, and results and analysis. The price models component is discussed in this chapter. Discussions on the remaining components are presented in the next chapter.

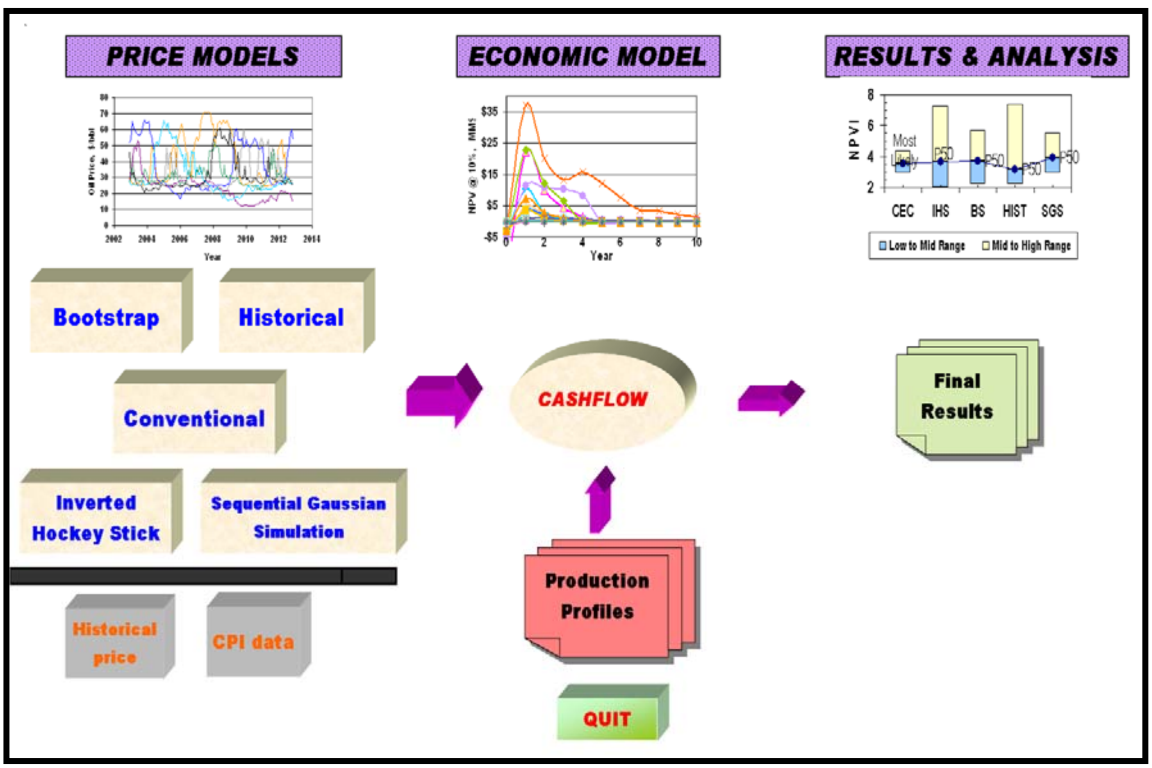

Fig. 3.1 – Consolidated project evaluation workflow

The price forecasts for all methods start from January 2005, with an oil price of \$48.47/bbl, which was the average West Texas Intermediate (WTI) price[8] in December 2004. **Fig. 3.2** shows the nominal monthly oil price data starting from January 1974. In addition, inflation-adjusted historical price data is illustrated in **Fig. 3.3.** An estimated average inflation rate of 0.392% per month (4.70% per year), determined from historical consumer price index data[22] **(Fig. 3.4)** was added to the constant dollar price forecasts generated by each method.

3.2 Price Forecasting Models

3.2.1 Conventional Forecasts

The conventional hockey stick method is based on the Delphi IX Survey of Oil Price Forecasts[23] which is the most recent Delphi survey available (**Fig. 3.5**). The Delphi forecasts are generated by the California Energy Commission (CEC), with the aid of a diverse "international panel of experts". The Commission has presented a series of Delphi oil price forecasts over the last two decades, beginning in the early 1980's.

The Delphi report presents three forecasts - low, most-likely, and high. According to the Commission, "90 percent of all possible oil price paths would lie above the estimated *low* price path," and "90 percent of all possible oil price paths would lie below the estimated *high* price path." Additionally, their most-likely oil price forecast is "the expected annual average price of internationally traded crude oil." A probability interval of 80% is therefore implied by the range of Delphi IX forecasts, and the low, most-likely, and high cases represent P10, P50, and P90 cases, respectively.

The Delphi IX forecasts are consistent with the conventional hockey stick forecasting approach. The low and most-likely forecasts decline initially before they flatten and then incline at a low rate. The high forecast increases smoothly and gradually from the beginning of the forecast. The forecasts do include some degree of short-term volatility, however, in the spread of prices between the low (\$16.92) and high (\$22.95) forecasts in the first year. The Delphi forecasts begin in 1997 and are presented in 1997 constant dollars. Since there were no Delphi forecasts available starting in 2005, when our economic analyses begin, we shifted the Delphi forecasts to begin in January 2005. This was done by calculating the percentage changes of the Delphi forecasts from the presumed known 1996 price and applying these percentage changes to the January 2005 starting price of $48.47/bbl used in our analyses.

While the imperfections in this approach are acknowledged, the resulting forecasts are believed to be representative of price forecasts commonly used in industry. The average future inflation rate of 0.392% per month was then applied to the constant dollar forecasts. **Fig. 3.6** shows the final 10-year price profiles used in the economic analyses for the conventional hockey stick method.

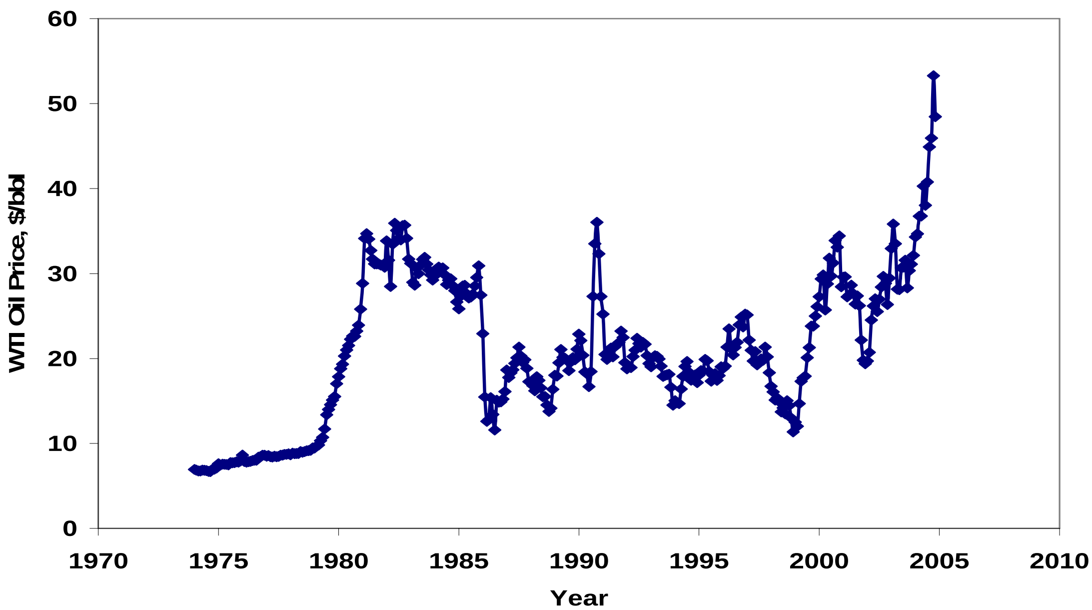

Fig. 3.2 - Nominal monthly WTI oil prices from January 1974 through December 2004 (Energy Information Administration, 2005)

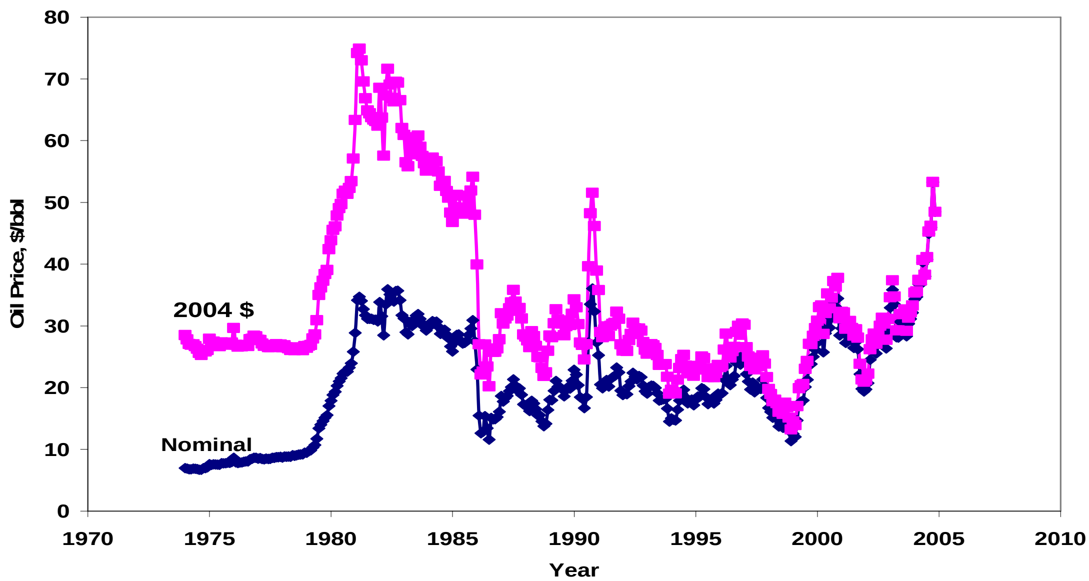

Fig.3.3 - Historical WTI oil prices, with and without inflation (Energy Information Administration, 2005)

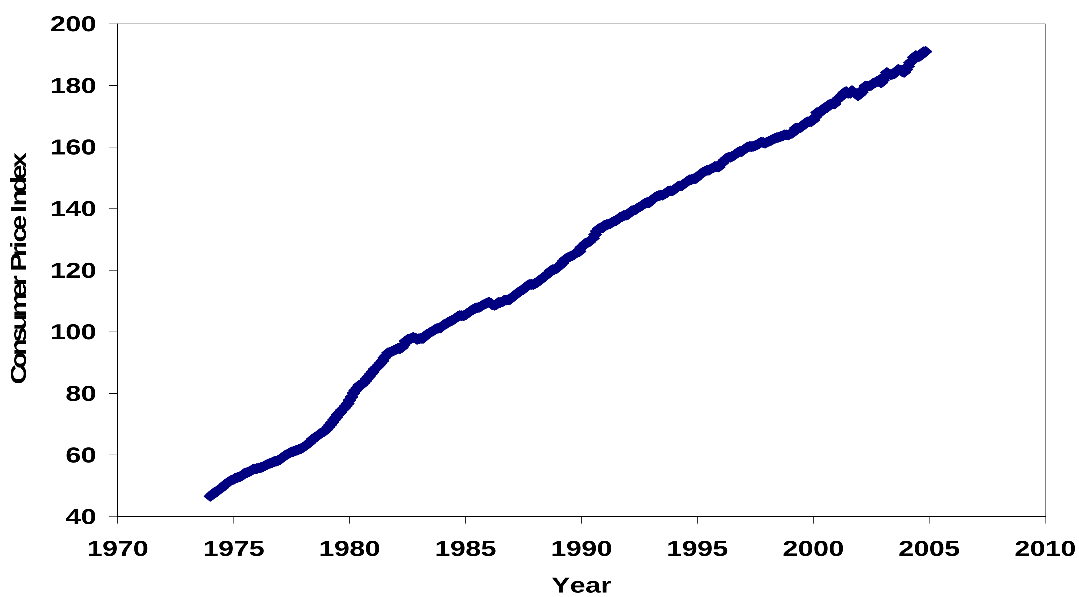

Fig. 3.4 - Consumer Price Index from January 1974 through December 2004 (Bureau of Labour Statistics, 2005)

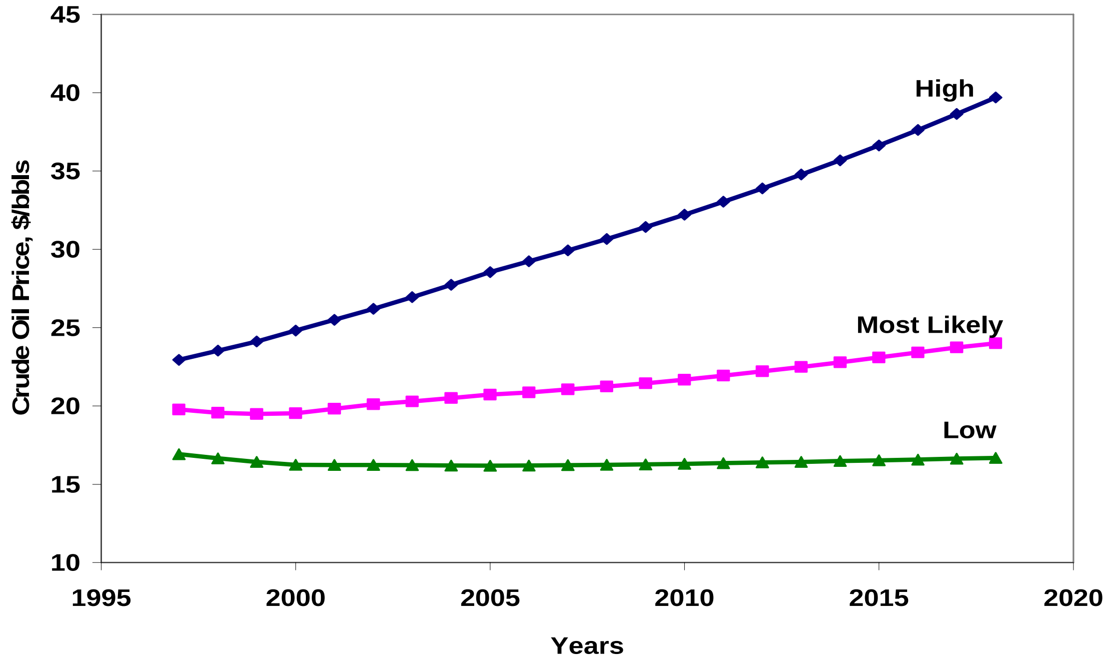

Fig. 3.5 - The Delphi IX crude oil price forecast (Nelson et al., 1997)

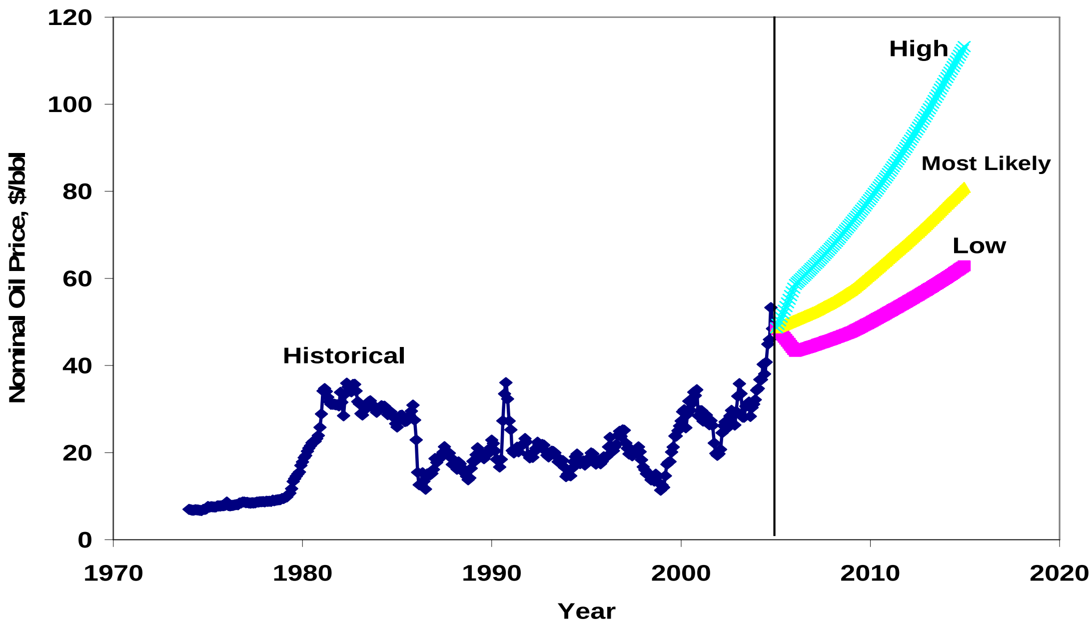

Fig. 3.6 - Conventional hockey stick oil price forecast, including inflation

3.2.2 Bootstrap Forecasts

The bootstrap technique was employed by McMichael[6] to generate forecasts and calculate economic indicators, and more recently by Akilu, McVay, and Lee.[11] The bootstrap method is a type of Monte Carlos simulation, requiring a method of generating or obtaining numbers that are random in some sense.[2] Each successive number in a sequence of random numbers must have an equal probability of taking on any one of the possible values (for example, every number between 0 and 1 has the same chance of occurring). Additionally, each number must be statistically independent of the other numbers in the sequence.

Randomly sampled historical price changes are used to construct multiple price forecasts. After adjusting historical prices for inflation, monthly fractional price changes (MPC) are calculated according to

$$MPC_i = \frac{P_i - P_{i-1}}{P_{i-1}} \tag{3.1}$$

Fig. 3.7 shows a graphical display of historical monthly fractional price changes, which served as the input data set for the bootstrap forecasts. Forecasts of monthly fractional price changes are then generated by randomly sampling the historical MPC with replacement. An example forecast is illustrated in **Fig. 3.8**. Being a random sampling with replacement, some data points in the original set may be repeated in the forecast multiple times, while other points may not be included at all.

Thereafter, cumulative fractional price changes (CMPC) are generated in the following manner:

$$CMPC_i = (1 + MPC_i) * (1 + MPC_{i-1}) * (1 + MPC_{i-2}) * \ldots * (1 + MPC_1) \tag{3.2}$$

CMPC is then applied to the forecast starting price, in our case, \$48.47/bbl in January 2005, to obtain an inflation-adjusted forecast. This technique is repeated as necessary to generate multiple price realizations. The average future inflation rate of 0.392% per month was then applied to the constant dollar forecasts. **Fig. 3.9** shows three sample realizations. Two hundred (200) total realizations were generated **(Fig. 3.10)**. The major weaknesses of the conventional bootstrap method, as observed in this study, are that it does not preserve the correlation of prices in time and the predicted prices may drastically exceed historical extremes, resulting in unrealistic results. In addition, the range of prices in the forecast is very sensitive to the starting price.

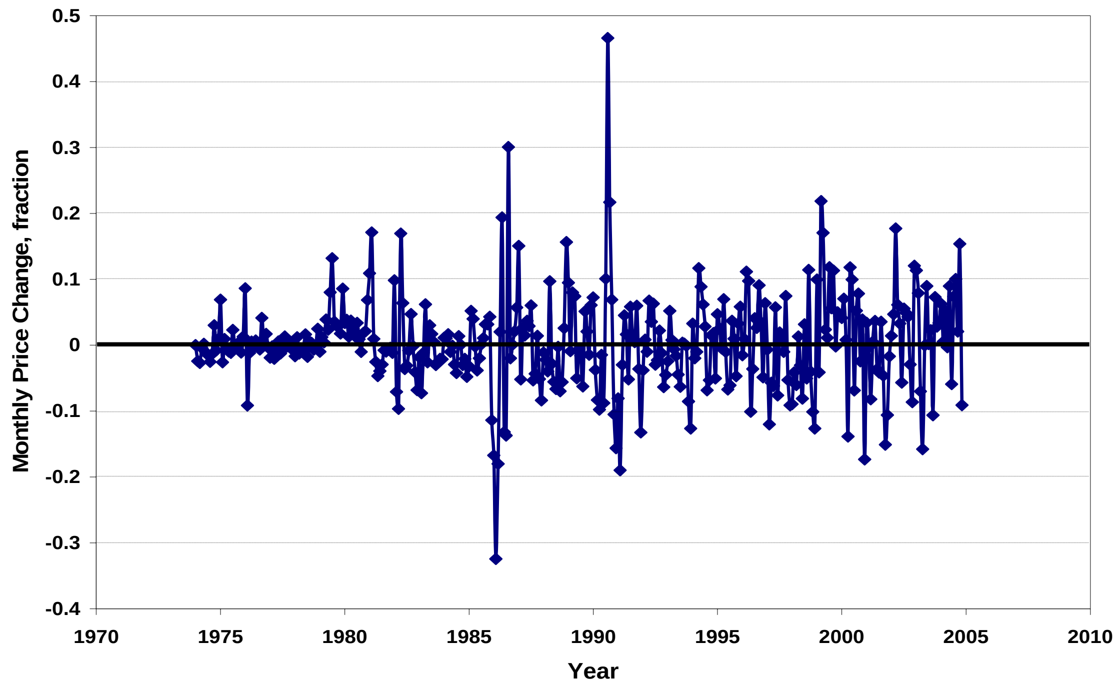

Fig. 3.7 - Historical monthly fractional price changes

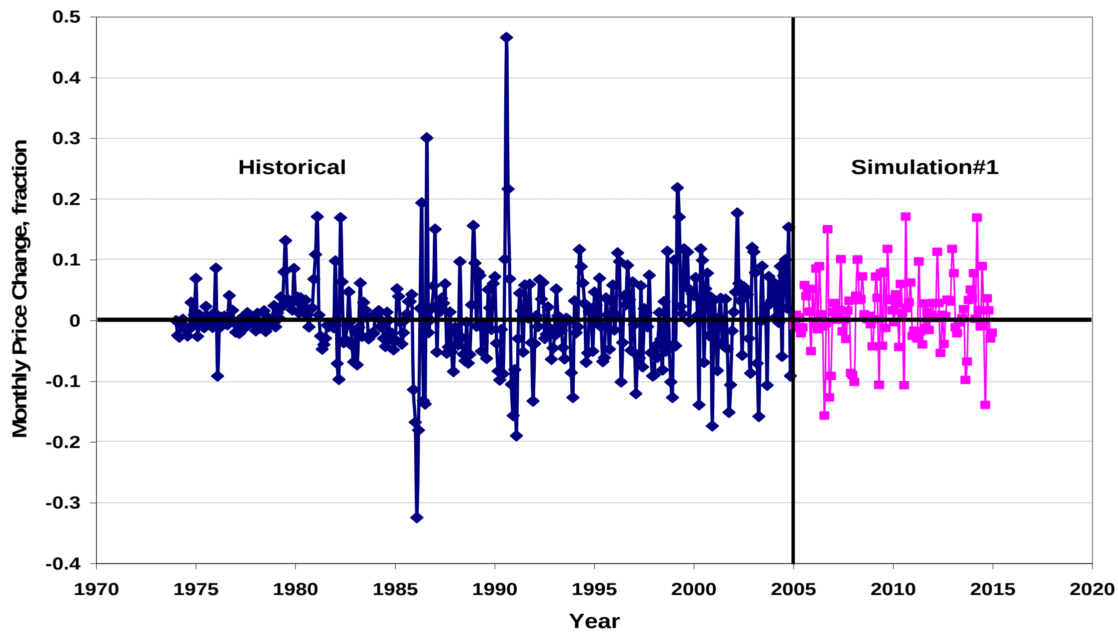

Fig. 3.8 - Monthly fractional price change forecast, Simulation #1

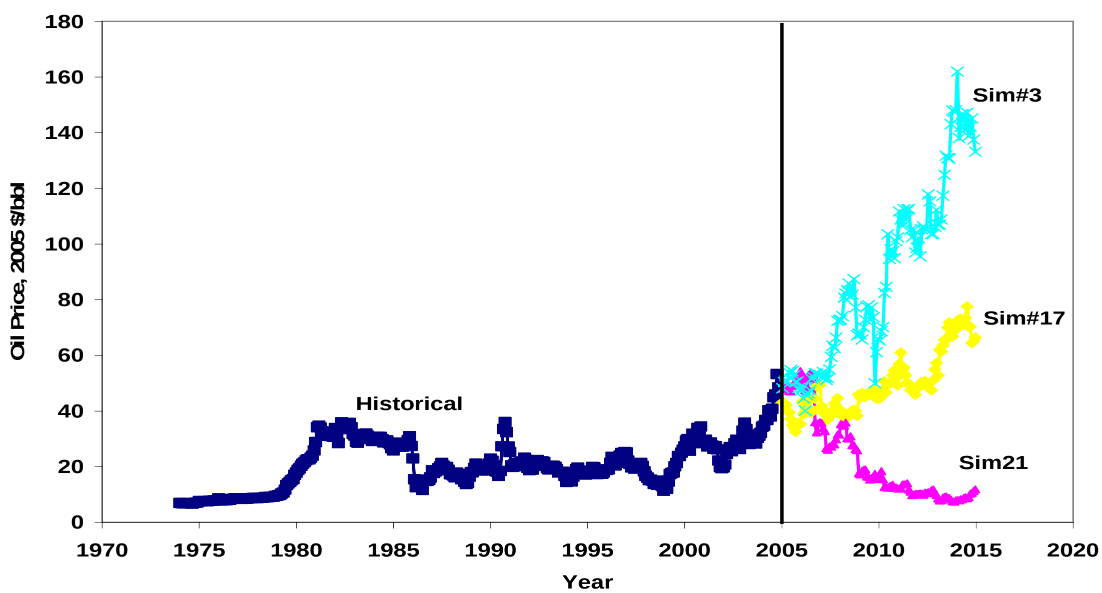

Fig. 3.9- Bootstrap method forecasts inflated-adjusted prices above and below historical limits

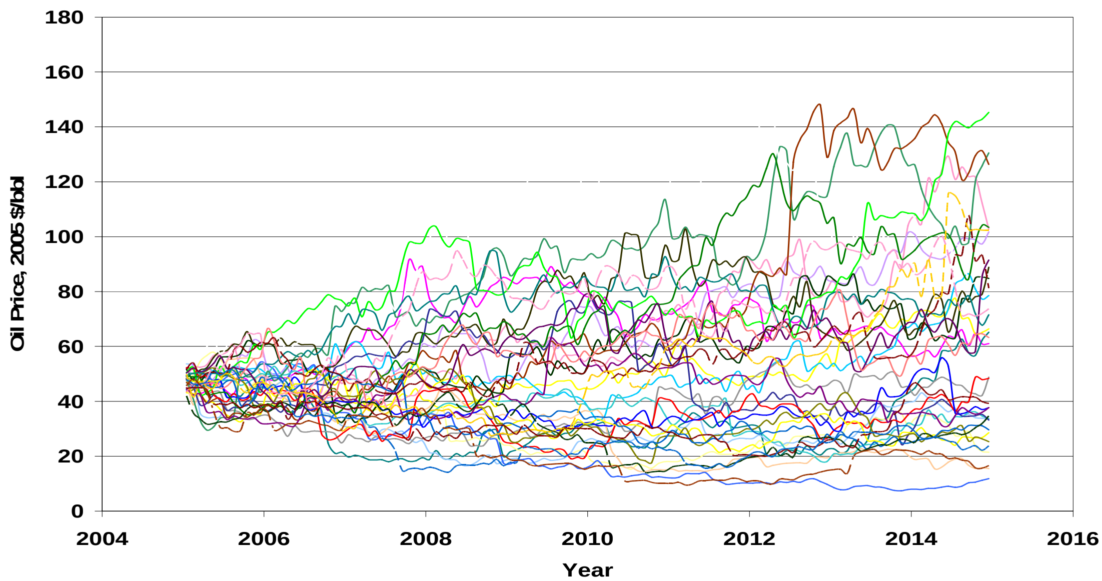

Fig. 3.10- Bootstrap method forecasts inflated-adjusted prices

3.2.3 Historical Forecasts

The Historical method was recently presented by Holmes, Mendjoge, and McVay.[10] The method assumes that future prices will experience similar variabilities as historical prices on a constant dollar basis. Thus, a stochastic representation of future prices can be approximated by examining many windows of historical prices. Application depends on the duration of a project. Multiple windows of historical uninflated price data are selected based on the expected project duration (e.g., 5, 10, 15 years). The forecasts are created by beginning the price windows at a user-defined "time zero" and incorporating expected future inflation into the realizations. 31 10-year price windows were selected starting in January 1974, January 1975, …, and January 2004. Price windows that extended beyond 2004 were "wrapped" back around to 1974. Wrapping yields more realizations and ensures that we are sampling all historical data equally. However, the method is only approximate because realizations are not equi-probable and can possess discontinuities at time zero of the forecast and at points where the prices wrap. **Fig. 3.11** and **Fig. 3.12** show the historical method price forecasts with and without inflation.

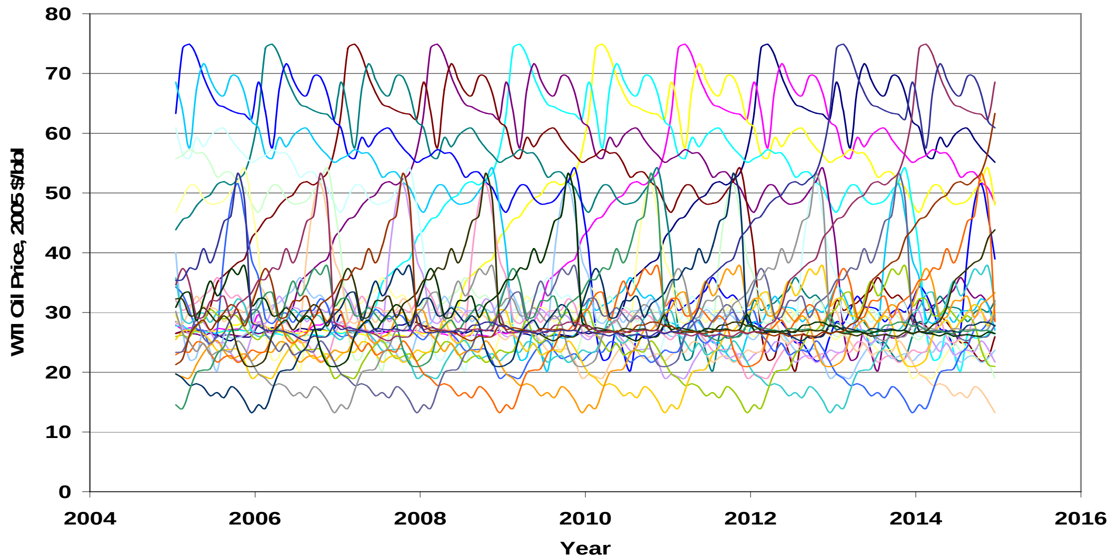

Fig. 3.11 - Historical method price forecasts, excluding inflation

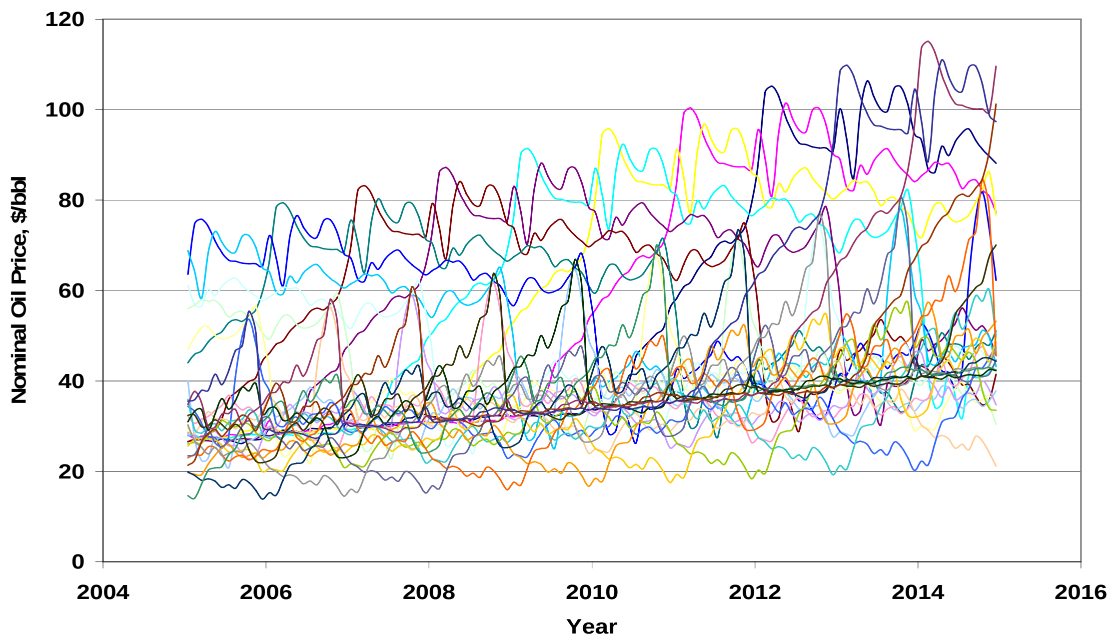

Fig. 3.12 - Historical method price forecasts, including inflation

3.2.4 Sequential Gaussian Simulation Forecasts

Sequential Gaussian Simulation (SGS) has historically been employed by geostatisticians to model spatial correlations between reservoir characteristics (e.g., porosity and permeability). However, Holmes, Medjoge, and McVay[10] recently extended SGS to forecast temporal price data. They used the technique to generate equiprobable sets of future oil price realizations. After removing inflation from historical price data, the normal score transform is developed to model the mean square difference between pairs of product price separated by a particular number of months. An algorithm randomly samples the distribution function and variogram, and a forecast is generated by sequentially predicting prices on a monthly basis. Finally, a normal score transform converts the price projections to uninflated prices, at which point an inflation rate may be assumed and factored into the forecasts.

In this study, we used the available geostatistical software packages, GEOEAS and GSLIB, to implement this method. The final price forecasts (60 realizations), without and with inflation are presented in **Fig. 3.13 and Fig. 3.14,** respectively.

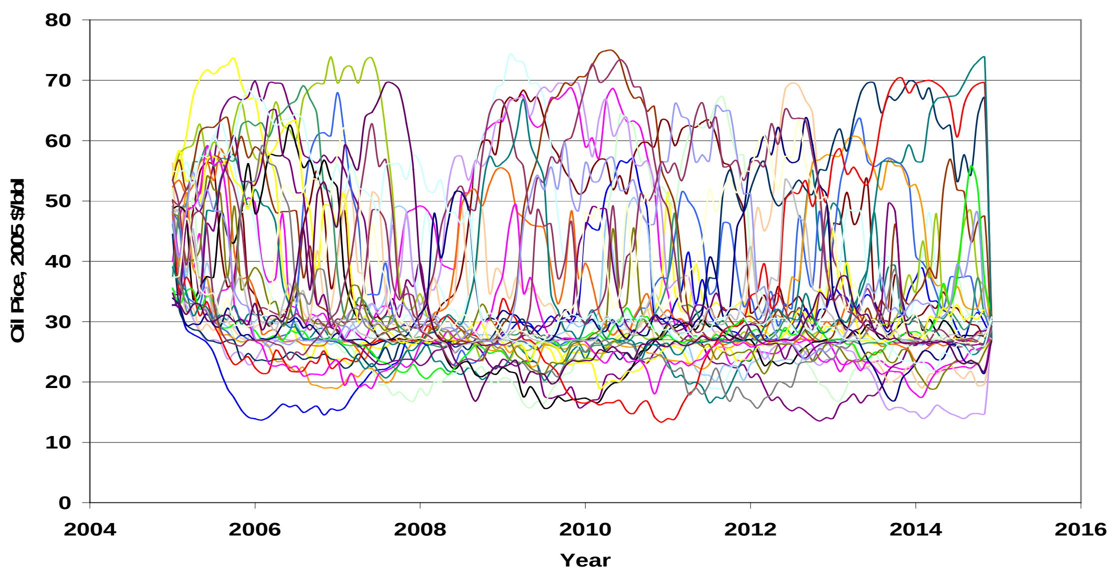

Fig. 3.13 - Example sequential Gaussian method price forecasts, excluding inflation

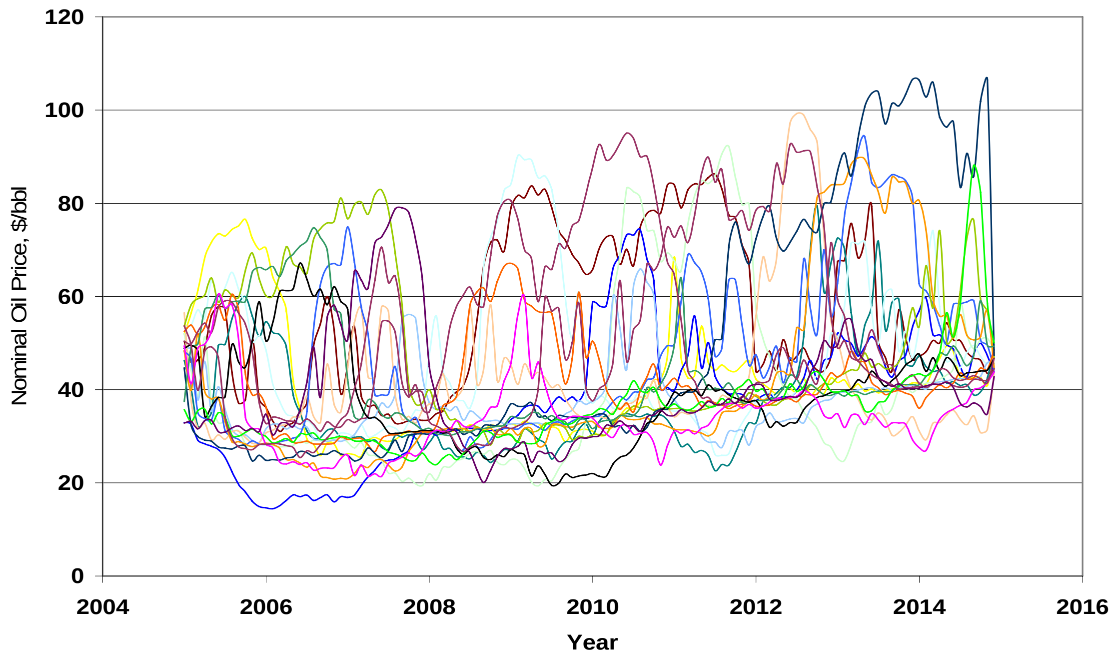

Fig. 3.14 - Example sequential Gaussian method price forecasts, including inflation

3.2.5 Inverted Hockey Stick Forecasts

Akilu, Lee, and McVay[11] recently proposed the Inverted Hockey Stick (IHS) Method as a means to better quantify uncertainty in future oil and gas prices. The IHS method generates low and high forecasts that honor the historical extremes of product prices on a constant dollar basis along with the maximum positive and negative historical rates of change.

The high and low cases are derived from the maximum sustained price slopes and the minimum and maximum prices from the uninflated historical price data. In the 'High-Full' profile in **Fig. 3.15**, the price increases from the starting price at a slope equal to the maximum sustained positive slope from the historical data (from approximately March 1979 to March 1981). The price increases until it reaches the maximum historical price, $74.89/bbl in 2005$, and is then maintained constant for the remainder of the forecast. In the 'Low-Full' profile, the price decreases at the maximum sustained negative slope (from approximately November 1985 to April 1986), but goes no lower than the minimum historical price, \$13.23/bbl in 2005. The historical slopes and limits represent 100% probability interval. However, the target was an 80% probability interval and was achieved by limiting the high and low price forecasts to 70% of the historical slopes and 70% of the differences between the starting price and the historical limit prices. The ‘High-70%’ and ‘Low-70%’ profiles in **Fig. 3.15** are the high and low cases for the Inverted Hockey Stick method.

For the middle case, the probability distribution of SGS forecasts was investigated and found to be approximately log normal. This distribution form was then used to calculate the IHS P50 or mean. The final nominal price profiles, as presented in **Fig. 3.16,** are obtained by applying an average future inflation rate of 0.392% per month.

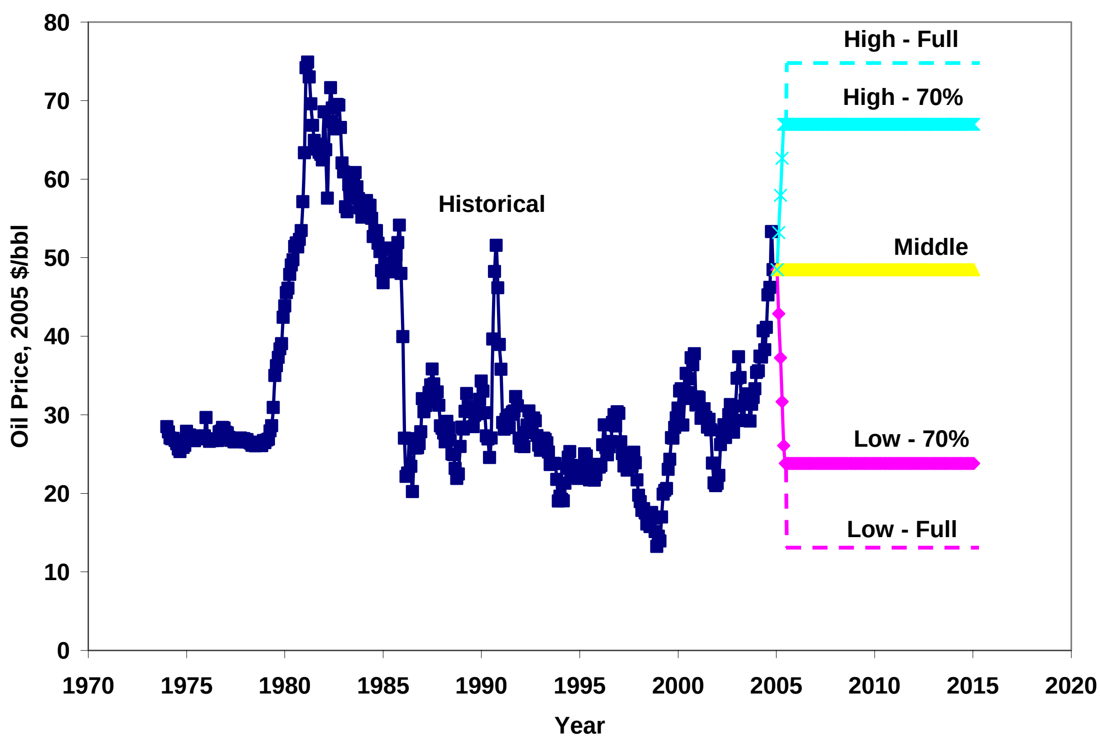

Fig. 3.15 - Inverted hockey stick forecasts, corresponding to 70% of historical price limits and maximum slopes

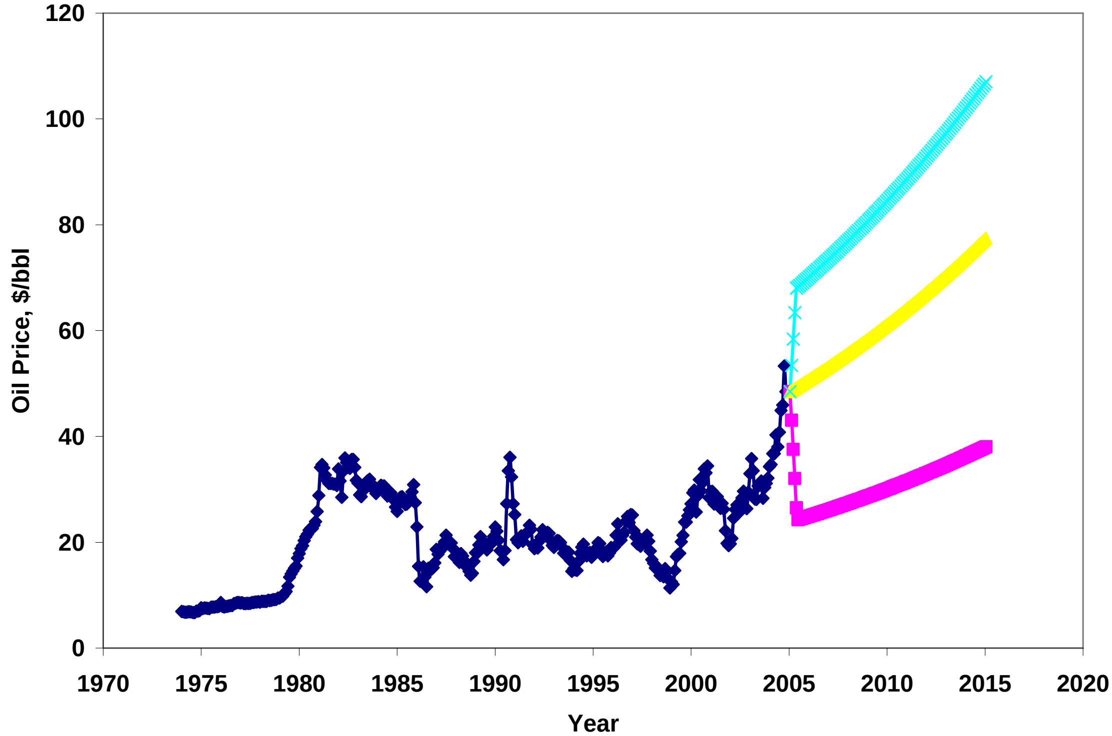

Fig. 3.16 - Inverted hockey stick forecasts, with inflation

3.3 Calibration of IHS Uncertainty Estimates

A consistent calibration procedure was developed to verify the reliability of the inverted hockey stick (IHS) method for quantifying oil price uncertainty. There will be no basis for improving IHS method unless its reliability can be validated. The approach was to contrast the bootstrap (BS) method with the sequential Gaussian simulation (SGS) method. BS and SGS methods are both stochastic in nature. They provide multiple realizations and full distributions of results. In the previous work,[11] IHS forecasts were calibrated against the BS method on the assumption that it was most accurate in quantifying price uncertainty. Investigations in this research show that this assumption may not be valid. The major weaknesses of the conventional bootstrap method are that it does not preserve the correlation of prices in time and the predicted prices may drastically exceed historical extremes, resulting in unrealistic results. In addition, the range of prices in the forecast is very sensitive to the starting price. From a technical standpoint, SGS should be the better benchmark because it honors the distribution and variability of historical prices. Though the range of uncertainty predicted by the SGS method is narrower than other alternative methods, it is the most rigorous and accurate method.[9] Results from this study show that the range of uncertainty predicted by SGS is about half of the range predicted by IHS. **Fig. 3.17** compares the ratio of uncertainty predicted by IHS to the range predicted by SGS and BS. The average ratio of uncertainty range predicted by IHS to the range predicted by SGS is 2.2 and is consistent across all the project cases for both 2003 and 2005 forecasts. Based on the relative advantages of SGS, IHS estimates are, therefore, better calibrated to SGS estimates.

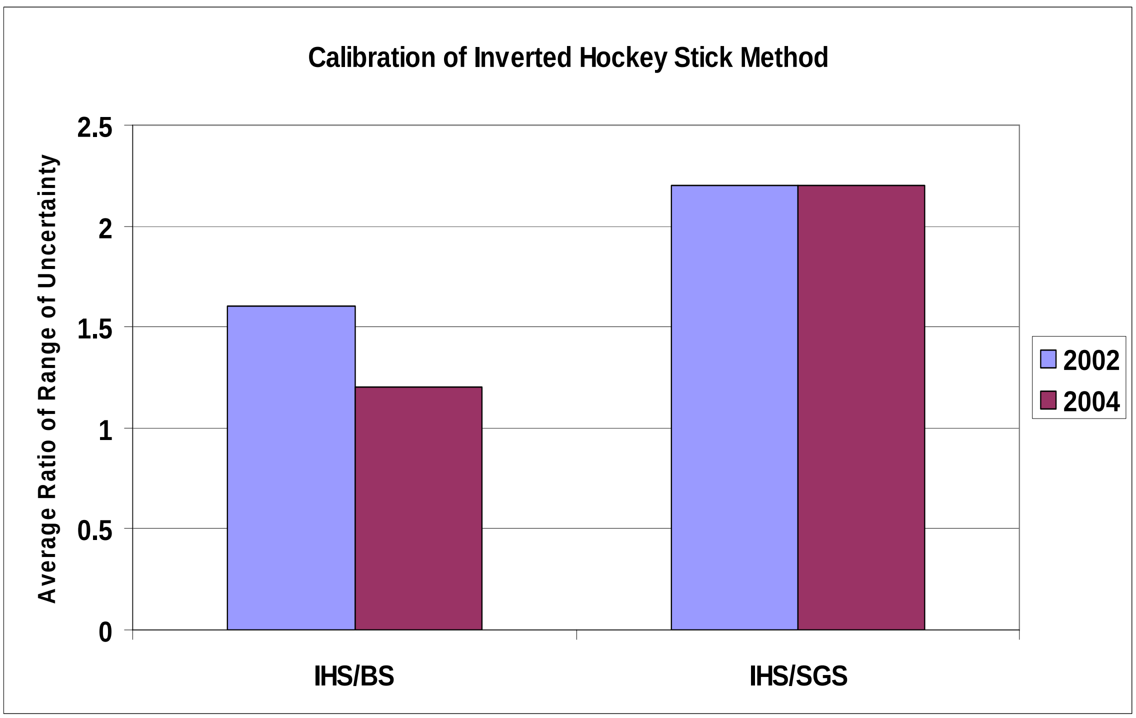

Fig. 3.17 – Calibration of uncertainty estimates

3.4 Distribution Forms

Oil companies typically use expectation (P50) or the best estimate in assessing the long-term performance of their assets for investment purposes.[24] This is particularly important while aggregating reserves volumes and their associated economic indicators, such as

NPV's, for different projects to arrive at a total investment portfolio of the company. In addition, this single point description of the economic indicator helps the decision makers to understand the investment's profitability in an easily interpretable manner. They work on the assumption that in the long run the sum of their expectation values will be realized, with the downside in one case compensated for by the upside in another situation. Providing this single point value is equally as important as the range of the possible values. There is a need, therefore, to address the P50 or mean values calculated by each method.

In their original work, Akilu e*t al.*[11] held the IHS most-likely forecast constant (at the most recently available product price) on a constant dollar basis. Olsen *et al.*[12] established P50 values for various project economic indicators by interpolating between high and low values on log probability plots. This approach was based on BS probability distributions which were found to be approximately log normal. The consequence is that any change in the basis for calibrating IHS forecasts may result in a change in the basis for predicting the mean or most likely values for the IHS method. There is a need, therefore, to investigate the probability distribution of SGS forecasts (rather than BS) to determine the distribution forms. This distribution form can then be used to calculate the IHS P50 or mean.

The probability distributions of NPV/I predicted by the SGS method were examined. The results show that the economic indicators for a typical project are log-normally distributed, as illustrated in **Fig. 3.18.** It should be noted that most of the projects are characterized by accelerated production scenarios. The plot is near linear, particularly between 10 and 90% cumulative probability, indicating the distribution is approximately log-normal.

The essence of this investigation is that if the distribution form of an economic indicator is known, it can then be possible to determine the entire distribution for a method, such as IHS in this case, that generates only two points (optimistic and pessimistic values) for economic parameters. This knowledge provides a basis for calculating the best estimate or mean and other statistical properties from the non-stochastic IHS method. A straight line is fitted through the endpoints from the IHS range on log probability plot and the values corresponding to any probability of interest from the line are read (**Fig. 3.19)**. This will allow decision makers to determine the potential profitability of a project based on the extent of risk they are willing to take.

Though the range of uncertainty predicted by IHS method is substantially wider than that of SGS, the use of the method would assist operators to recognize that there is much more uncertainty in oil and gas development projects than has been previously acknowledged. According to Akilu e*t al.*,[11] acknowledging greater uncertainty should force operators to think twice about, or study harder, cases that have substantial downside potential. It may cause them to re-evaluate projects that they would walk away from without knowledge of the potentially greater upside potential.

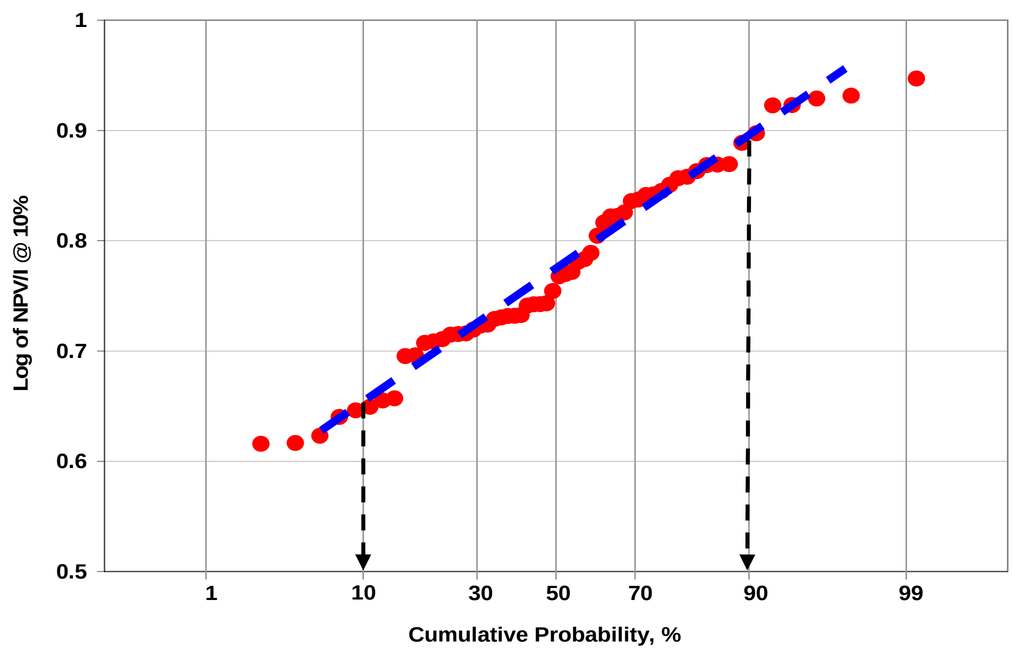

Fig. 3.18 – NPV/I @ 10% for typical project case is approximately log-normally distributed (Sequential Gaussian simulation analysis)

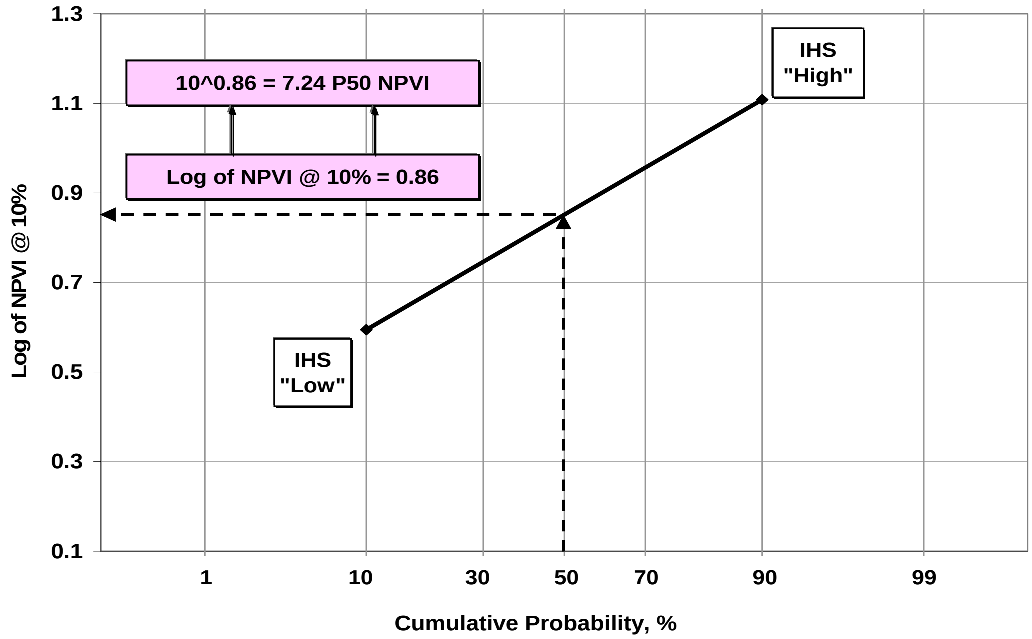

Fig. 3.19 – Inverted hockey stick – "P50" economic indicator values

CHAPTER IV

APPLICATION AND RESULTS

4.1 Consolidated Economic Model and Application

In the economic component of the workflow **(Fig. 4.1)**, the economical analyses were carried out for the 5 price models with a combined number of 297 realizations and 26 project cases. Of these projects, 23 represent actual or proposed petroleum industry investments presented by Olsen *et al.*[12,13] The investments are diverse, as they include artificial lift installations, tubing upgrades, hydraulic fractures, development and exploratory wells, re-entries, and an acquisition. Majors and independents implemented or planned the projects in various hydrocarbon provinces throughout the United States, including the Gulf of Mexico (shelf and deepwater), Mid-Continent, South Texas, East Texas, West Texas, Rocky Mountains, and onshore Gulf Coast. **Fig. 4.2** shows the production profiles for some of the projects. Most of the 23 industry projects exhibit accelerated cash flow profiles, as illustrated in **Fig. 4.3.**

The remaining three projects are synthetic cases based on cash flow profiles presented by Capen, Clapp, and Phelps.[25] These cases feature distinctly different cash flow profiles exhibited by petroleum industry investments - *accelerated*, *uniform* and *delayed*. **Fig. 4.4** displays examples of cash flow profiles similar to those presented by Capen *et al*.[25] In an *accelerated* cash flow profile, the majority of positive cash flow generated by a project is received shortly after the initial investment. The *uniform* cash flow profile is distinguished by a constant level of cash flow throughout the majority of the project's life. A *delayed* cash flow profile is characterized by receipt of the majority of positive cash flow long after the initial investment. **Table B-1** (Appendix B) shows the economic parameters used in this study. Also Table B-2 shows the historical oil price and consumer price indices.

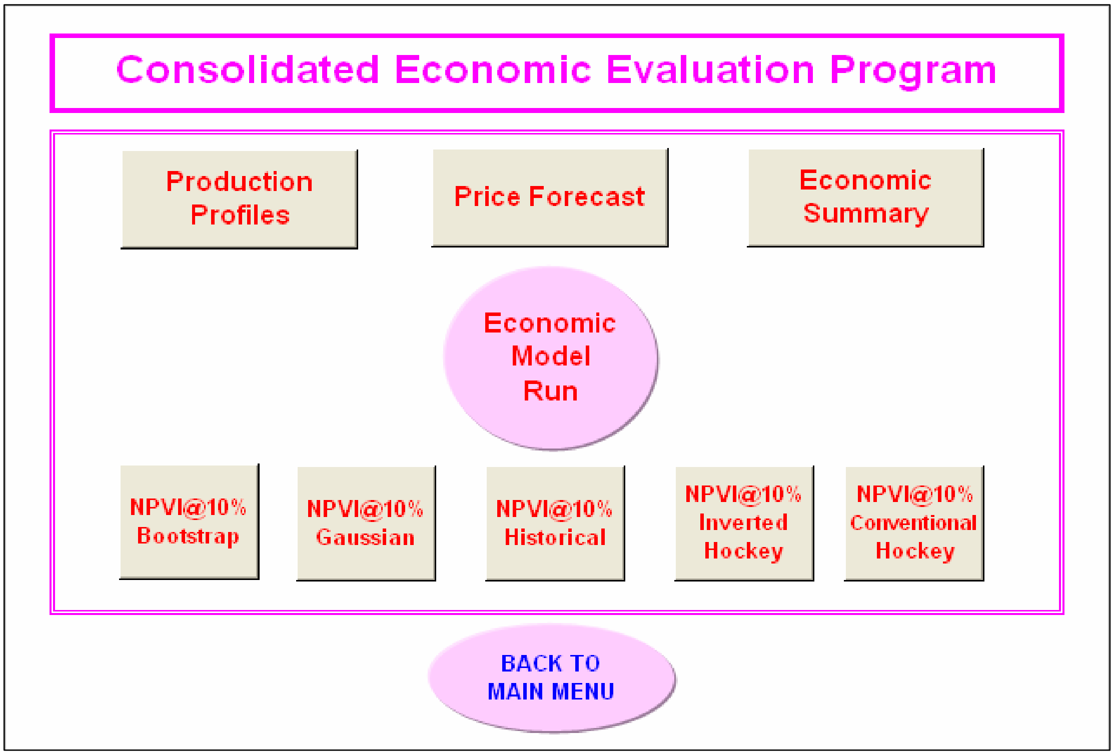

Fig. 4.1 –Consolidated economic model

The overall question addressed in this study is whether further investigations of the applicability of alternative methods with the sustained prevailing high prices will validate the conclusions in the previous studies and confirm their relative advantages over the conventional methods. For ease of accurate comparison with the previous studies,[10,11] oil prices were exclusively used in this study (i.e., no gas price forecasts) and the project durations were limited to ten years. The projected gas rates from the industry projects were converted to oil rates using a gas-to-oil equivalence of 6 Mcf gas to 1 bbl oil. Production that was predicted to occur in industry projects after the ten year "limit" was not considered in our analysis.

Production costs were varied with oil price, as reported by Holmes *et al.*[10] **Fig 4.5** shows the correlation between historical oilfield production costs and oil prices for the period 1986-2001, obtained from the Energy Information Administration (2003b).[26]

Widely used economic indicators, such as net present value, internal rate of return and investment efficiency, were used to compare the range of uncertainty in economic indicators as predicted by the various methods.

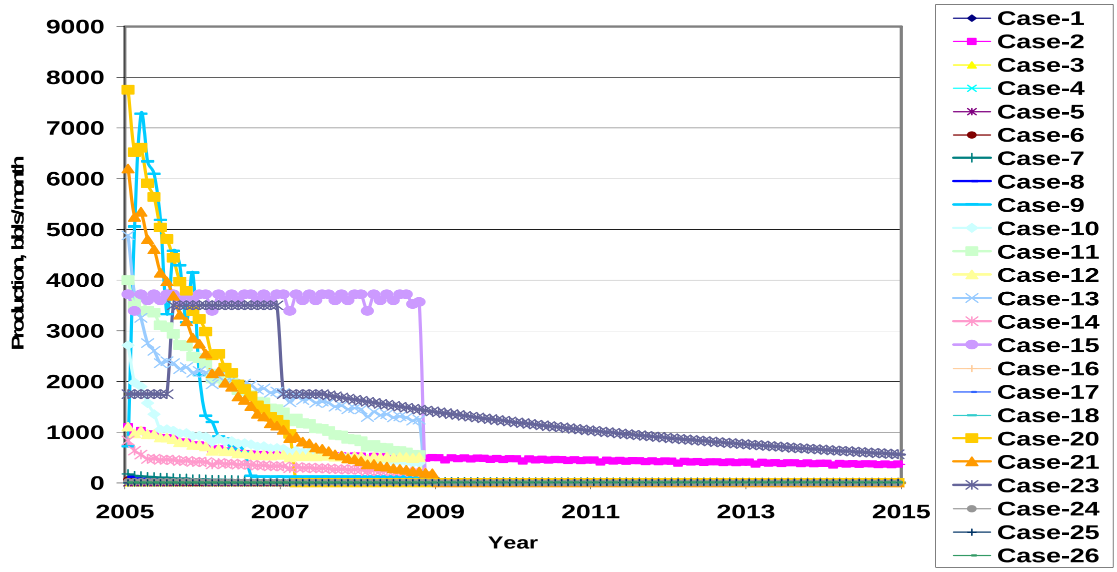

Fig. 4.2 - Production profiles for some of the 23 industry cases

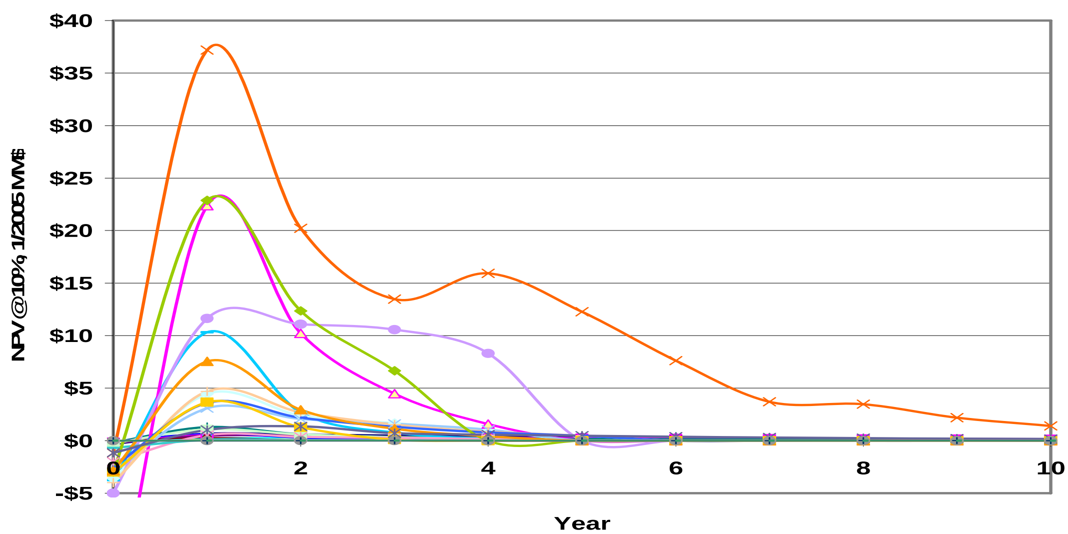

Fig. 4.3 - Typical cashflow profiles for the 23 industry cases with inverted hockey stick most-likely price forecast

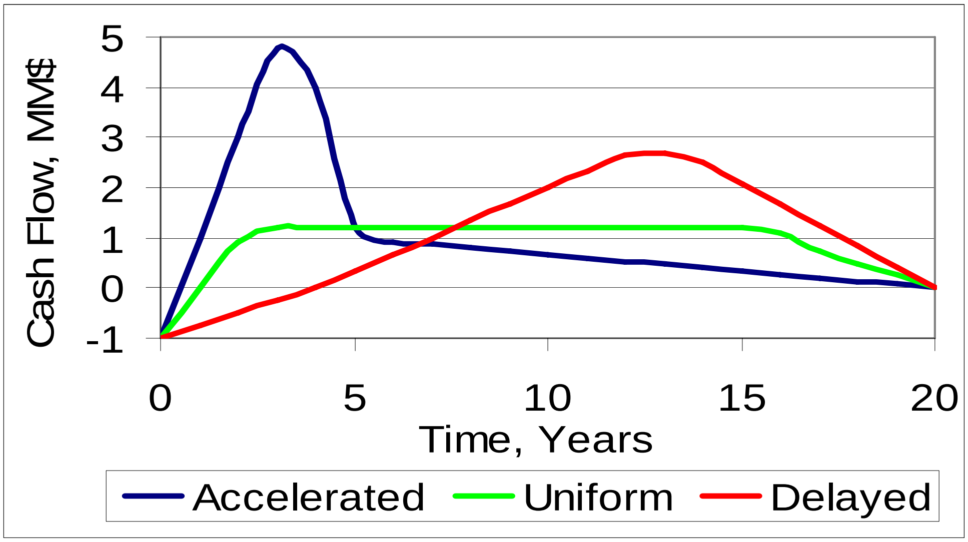

Fig. 4.4 – Accelerated, uniform, and delayed cash flow profiles for theoretical projects

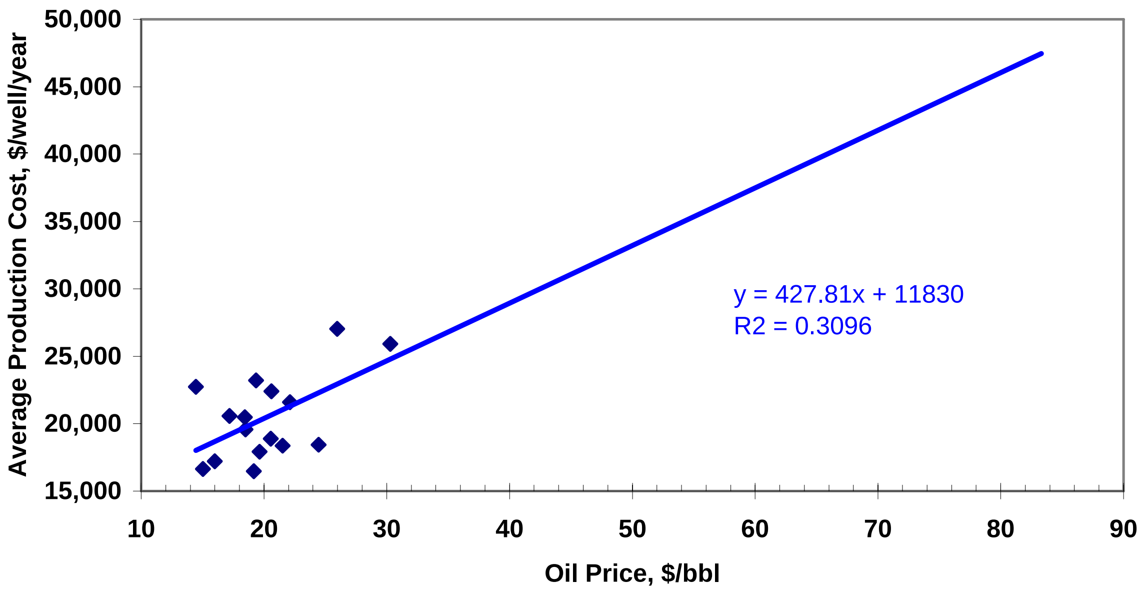

Fig. 4.5 - Correlation of production costs to crude oil price (Energy Information Administration, 2003)

4.2 Comparative Analysis of Uncertainty Estimates

The comparisons of ranges of uncertainty in economic indicators resulting from the various methods were carried out. **Tables 4.1 – 4.4** show the ranges of uncertainty for the 26 project cases. One obvious observation is that the range of uncertainty for the economic indicators predicted by conventional methods (CHS) is generally narrower than those predicted by all the alternative techniques- inverted hockey stick (IHS), bootstrap (BS), historical (HIST) and sequential Gaussian simulation (SGS).

Table 4.1 Ranges of values of NPV/I @ 10% for Cases 1-5

		CHS	IHS	BS	HIST	SGS
Case-1	**High**	10.961	12.830	16.374	9.426	7.817
	Low	7.433	3.929	5.894	3.733	4.444
	Most Likely	8.877	7.244	10.057	4.944	5.769
Case-2	**High**	22.287	25.288	34.691	16.797	14.552
	Low	14.783	8.042	11.567	7.711	9.770
	Most Likely	17.770	14.454	21.135	9.705	11.772
Case-3	**High**	8.960	10.455	13.822	7.888	6.613
	Low	6.034	3.205	4.698	3.242	3.597
	Most Likely	7.229	6.026	8.167	4.227	4.633
Case-4	**High**	16.394	19.351	22.671	15.293	12.576
	Low	11.630	6.521	9.812	6.309	7.105
	Most Likely	13.627	12.303	15.137	8.188	9.193
Case-5	**High**	9.512	11.359	13.092	9.006	7.209
	Low	6.713	3.595	5.714	3.417	3.979
	Most Likely	7.891	6.310	8.822	4.680	5.302

Table 4.2 Ranges of values of NPV/I @ 10% for Cases 6-12

		CHS	HIS	BS	HIST	SGS
Case-6	**High**	6.928	9.273	8.289	8.118	7.645
	Low	5.846	2.929	4.608	0.903	2.793
	Most Likely	6.370	5.129	6.310	2.656	4.543
Case-7	**High**	19.109	22.574	26.223	17.270	15.166
	Low	14.088	8.084	12.436	7.389	9.499
	Most Likely	16.181	13.183	17.728	9.460	11.283
Case-8	**High**	21.972	27.103	26.947	22.651	20.414
	Low	17.566	10.194	15.671	7.842	11.087
	Most Likely	19.505	16.596	20.297	10.977	14.188
Case-9	**High**	3.064	4.051	3.689	3.259	3.220
	Low	2.371	0.974	2.083	0.777	1.196
	Most Likely	2.689	1.995	2.771	1.215	1.737
Case-10	**High**	1.908	2.504	2.663	1.965	1.604
	Low	1.295	0.402	1.057	0.211	0.526
	Most Likely	1.562	1.012	1.699	0.581	0.905
Case-11	**High**	7.886	9.968	9.691	8.404	7.460
	Low	6.050	3.076	5.131	2.328	3.485
	Most Likely	6.872	5.623	7.090	3.487	4.731
Case12	**High**	1.080	1.635	1.454	1.295	1.110
	Low	0.695	-0.050	0.467	-0.338	0.012
	Most Likely	0.873	1.303	0.867	-0.003	0.338

Table 4.3 Ranges of values of NPV/I @ 10% for Cases 13-19

		CHS	HIS	BS	HIST	SGS
Case-13	**High**	1.902	2.480	2.735	1.923	1.500
	Low	1.237	0.348	0.966	0.192	0.464
	Most Likely	1.524	0.912	1.672	0.577	0.839
Case-14	**High**	-0.341	-0.183	-0.168	-0.302	-0.408
	Low	-0.490	-0.715	-0.575	-0.795	-0.694
	Most Likely	-0.424	-0.415	-0.404	-0.685	-0.594
Case-15	**High**	8.232	10.061	11.256	8.188	6.497
	Low	5.850	2.969	4.897	2.646	3.280
	Most Likely	6.867	5.248	7.470	3.854	4.493
Case-16	**High**	1.820	2.418	2.566	1.863	1.516
	Low	1.193	0.292	0.939	0.123	0.421
	Most Likely	1.466	0.126	1.598	0.482	0.787
Case-17	**High**	2.674	3.448	3.724	2.708	2.224
	Low	1.832	0.659	1.490	0.441	0.820
	Most Likely	2.197	1.496	2.394	0.914	1.304
Case-18	**High**	-0.700	-0.598	-0.578	-0.692	-0.758
	Low	-0.794	-0.931	-0.846	-1.044	-0.940
	Most Likely	-0.754	-0.747	-0.740	-0.944	-0.861
Case-19	**High**	14.315	17.673	17.207	15.186	13.881
	Low	11.290	6.381	10.149	5.499	7.154
	Most Likely	12.648	10.715	12.953	7.096	9.070

Table 4.4 Ranges of values of NPV/I @ 10% for Cases 20-26

		CHS	IHS	BS	HIST	SGS
Case-20	**High**	0.580	1.015	0.783	0.788	0.751
	Low	0.355	-0.211	0.162	-0.463	-0.185
	Most Likely	0.464	0.476	0.450	-0.230	0.076
Case-21	**High**	3.575	4.595	4.354	3.786	3.503
	Low	2.748	1.281	2.413	0.968	1.500
	Most Likely	3.120	2.455	3.231	1.470	2.021
Case-22	**High**	118.148	137.374	169.360	102.436	90.649
	Low	84.904	49.560	71.322	47.159	57.283
	Most Likely	98.561	83.176	110.058	59.751	68.498
Case-23	**High**	4.676	5.462	7.398	3.760	3.071
	Low	2.936	1.318	2.263	1.363	1.646
	Most Likely	3.646	2.692	4.256	1.900	2.170
Case-24	**High**	0.878	1.330	1.384	0.947	0.653
	Low	0.432	-0.221	0.217	-0.415	-0.151
	Most Likely	0.628	0.653	0.704	-0.123	0.152
Case-25	**High**	0.455	0.480	2.156	0.084	-0.133
	Low	-0.210	-0.596	-0.610	-0.677	-0.556
	Most Likely	0.038	0.011	0.330	-0.512	-0.438
Case-26	**High**	1.807	2.080	3.614	1.090	0.775
	Low	0.841	0.082	0.382	0.105	0.280
	Most Likely	1.220	0.398	1.637	0.325	0.485

Figs. 4.6 to 4.9 show the ranges in investment evaluation indicators as determined by conventional, inverted hockey stick, bootstrap, historical and Gaussian simulation methods. The figures show the relationships between the most-likely values for the five methods as well as the difference in ranges. All of the four alternative price forecasting methods predict a wider range of uncertainty in NPVI than the CHS forecast. **Fig. 4.10** presents ranges for NPVI values averaged over all 26 cases predicted by the five forecasting methods. Although not shown, the alternative forecasting methods also predicted greater variability (i.e., wider ranges) in NPV and IRR values for the 23 industry projects and three synthetic cases.

These results indicate that conventional methods routinely underestimate uncertainty. All four alternative forecasting techniques can provide operators with more reliable quantification of the uncertainty inherent in their investment decisions than provided by conventional methods currently in widespread use. The four alternative methods have unique strengths and weaknesses that may affect their applicability in particular situations. The SGS methods is the most rigorous and accurate method; however, it is also the most difficult to apply. The IHS method serves as a reasonable approximation, and can be easily incorporated into existing procedures and software.

In summary, the four alternative forecasts predicted wider range of uncertainty in NPV/I @ 10% than conventional forecasts in following proportions:

- IHS Method: 3.3 * {CEC NPVI range} for all 26 cases
- BS Method: 2.8 * {CEC NPVI range} for all 26 cases
- HIST Method: 2.8 * {CEC NPVI} range for 24 of 26 cases
- SGS Method: 2 * {CEC NPVI} range for 16 of 26 cases

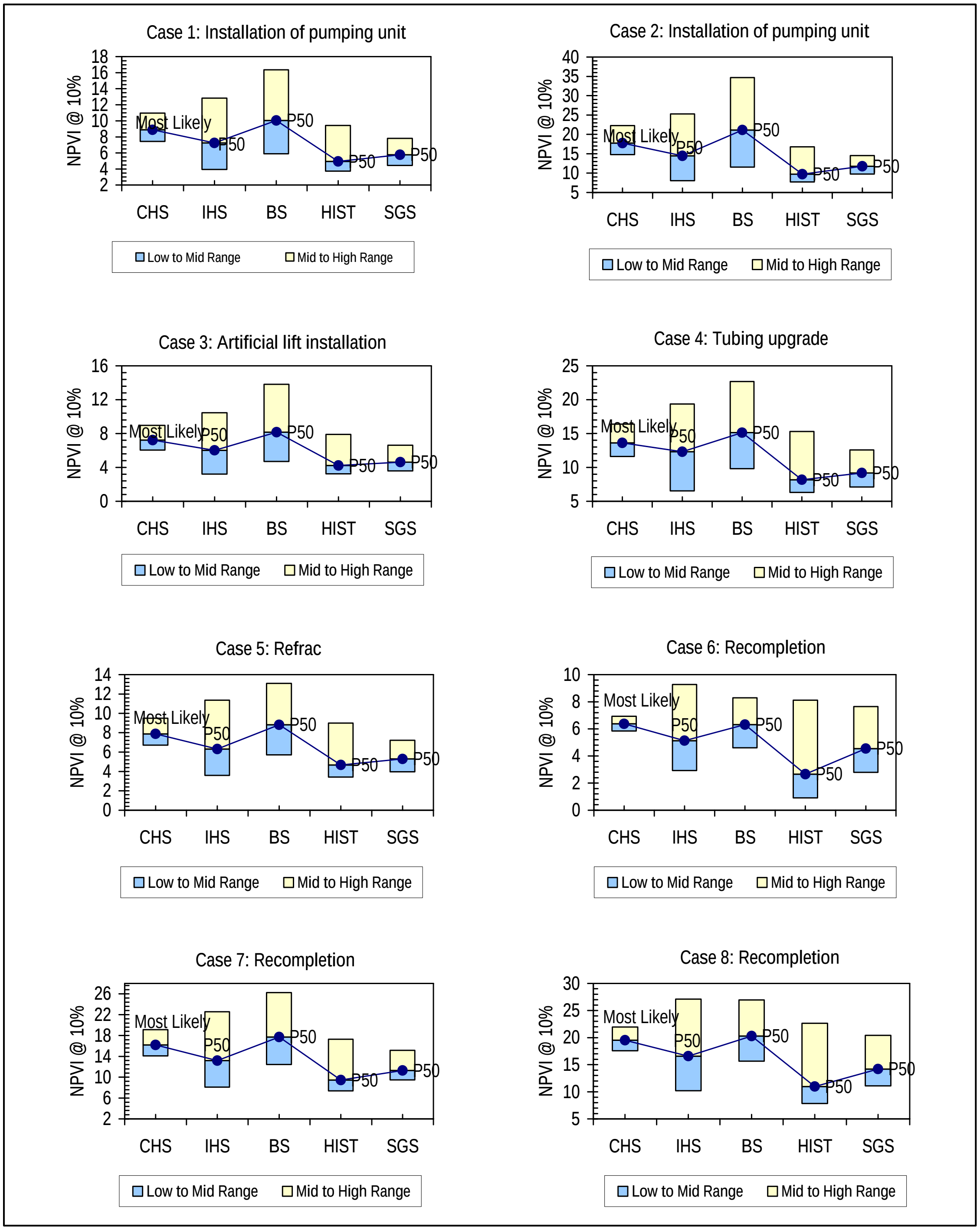

Fig. 4.6 - Comparison of uncertainty quantification methods for Cases 1 - 8

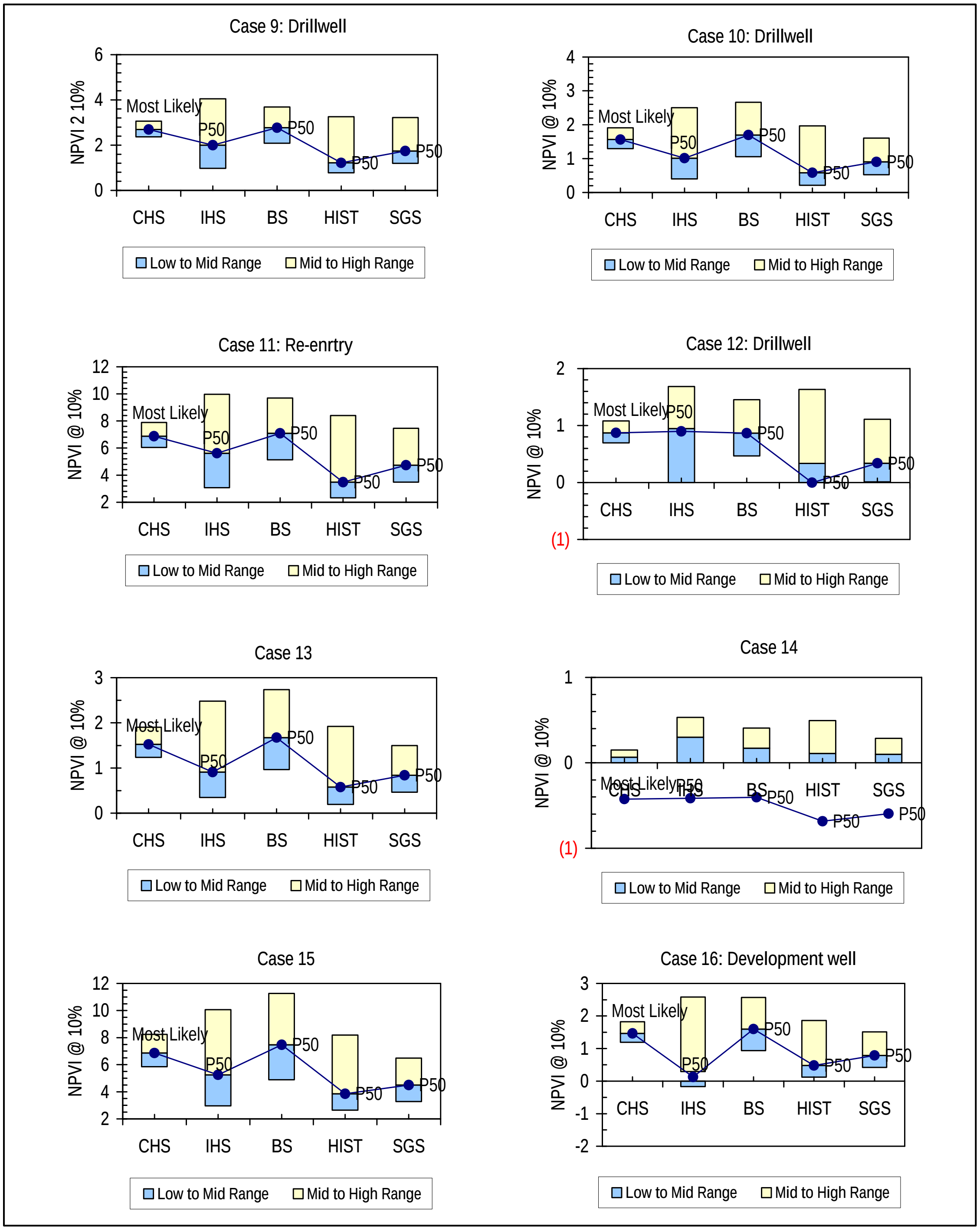

Fig. 4.7 - Comparison of uncertainty quantification methods for Cases 9 - 16

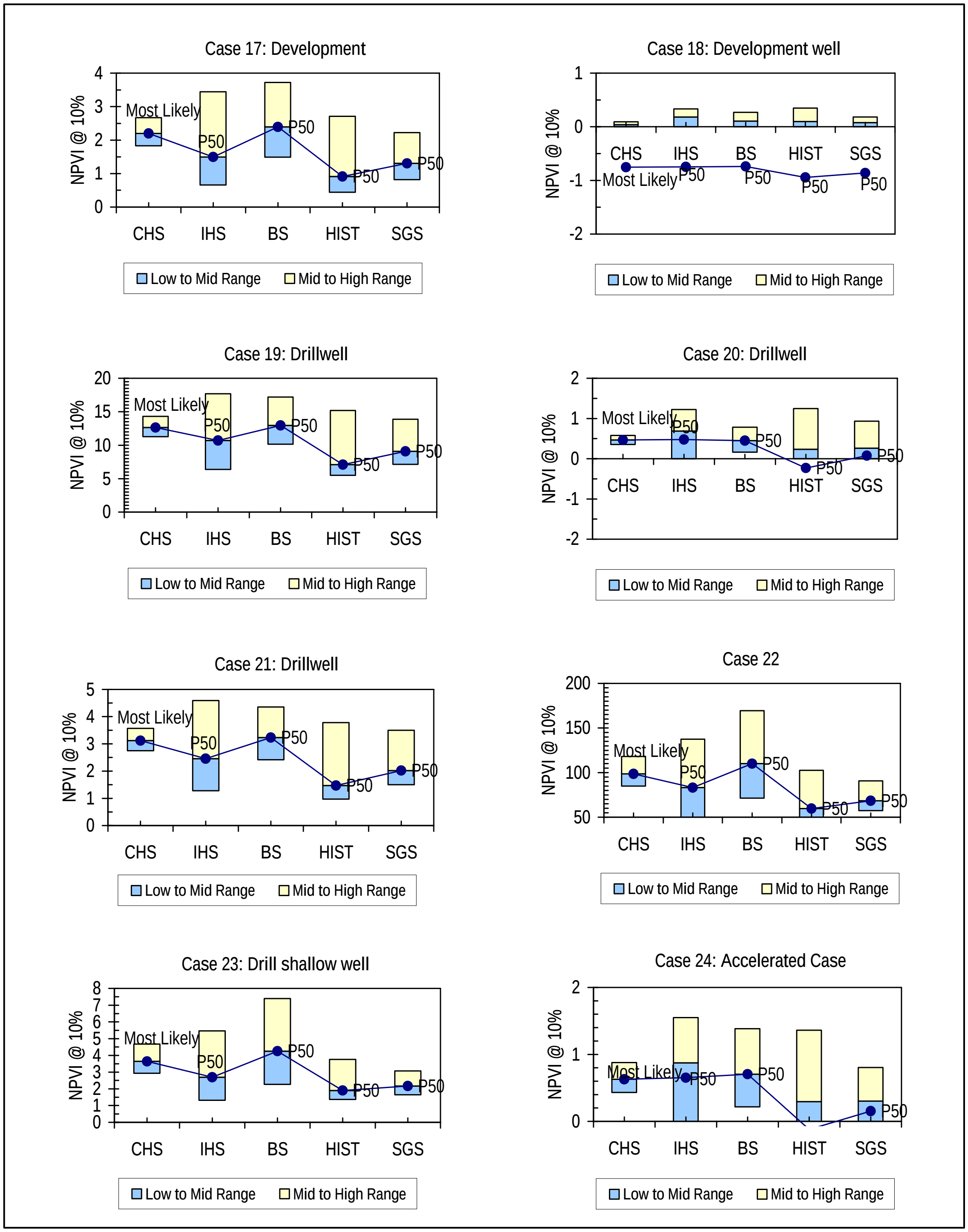

Fig. 4.8 - Comparison of uncertainty quantification methods for Cases 17 - 24

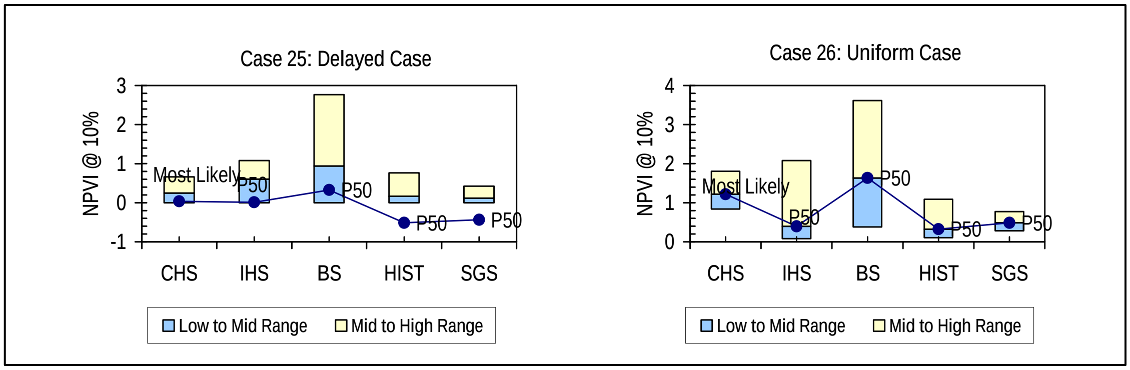

Fig. 4.9 - Comparison of uncertainty quantification methods for Cases 25 - 26

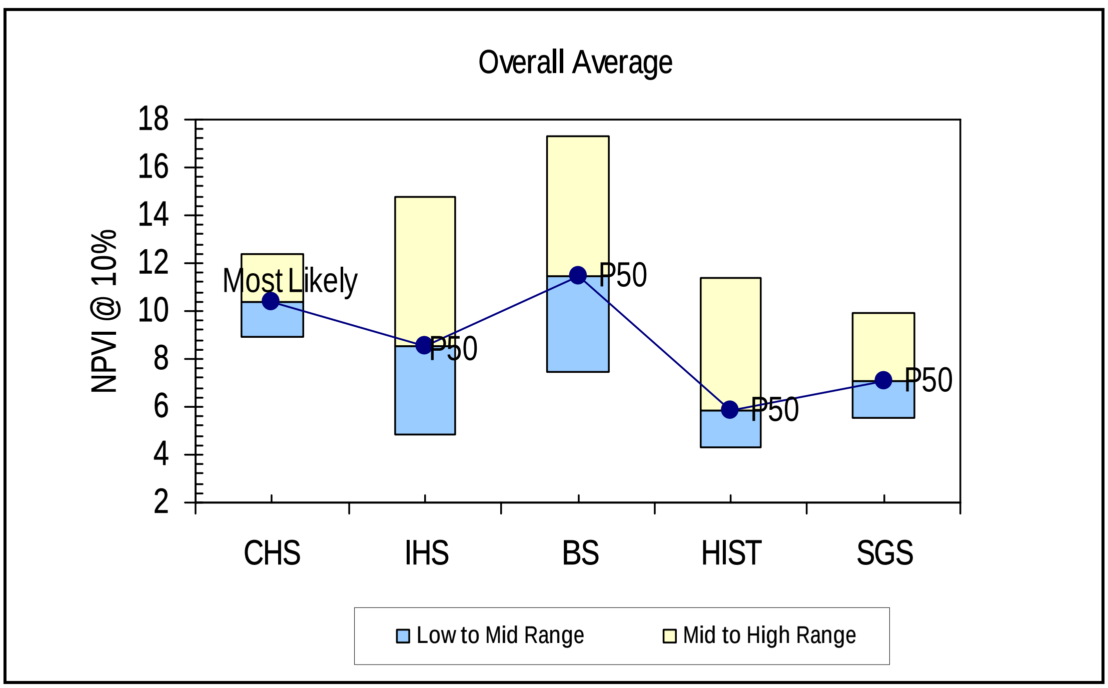

Fig. 4.10 - Comparison of uncertainty quantification methods: Average range of uncertainty in NPV/I @ 10% for all cases

CHAPTER V

CONCLUSIONS

This research investigated the impacts of price uncertainty quantification models on project evaluations using both industry and synthetic cases at the prevailing high prices of oil and gas. The following are conclusions drawn from the results of this study.

1. Conventional price forecasts commonly used in the industry typically underestimate the range of uncertainty in oil and gas prices.
2. The recently developed forecasting techniques evaluated in this research are based on historical price volatilities and better quantify uncertainty in future price paths. The four alternative methods predicted wider ranges of uncertainty in NPVI @ 10% and other economic indicators than conventional forecasts in the following proportions:
   i. IHS Method: 3.3 * {CHS NPVI range} for all 26 cases
   ii. BS Method: 2.8 * {CHS NPVI range} for all 26 cases
   iii. HIST Method: 2.8 * {CHS NPVI} range for 24 of 26 cases
   iv. SGS Method: 2 * {CHS NPVI} range for 16 of 26 cases
3. The four alternative methods have unique strengths and weaknesses that may affect their applicability in particular situations. Three of the methods, namely BS, HIST and SGS, are stochastic in nature by providing multiple realizations and full distributions of results. While stochastic methods can improve the assessment of price uncertainty, they can also be tedious to implement. Inverted hockey stick, the only non-stochastic method, is considered to be an easily applied alternative to stochastic methods. The IHS method captures the uncertainty predicted by stochastic methods, but with the ease of calculation of the conventional hockey stick method. The IHS method, therefore, serves as a reasonable approximation.
4. A new calibration of uncertainty estimates predicted by the IHS method, based on SGS estimates, is recommended. Though the range of uncertainty predicted

by the SGS method is narrower than other alternative methods, it is the most rigorous, accurate and consistent. In previous work, IHS forecasts were calibrated against the traditional BS method on the assumption that it was most accurate in quantifying price uncertainty. Investigations in this research show that this assumption may not be valid. The major weaknesses of the conventional bootstrap method are that it does not preserve the correlation of prices in time and the predicted prices may drastically exceed historical extremes resulting in unrealistic results. In addition, the range of prices in the forecast is very sensitive to the starting price. These weaknesses make the method less consistent than the SGS method.

5. Results from this study show that the ranges of uncertainty predicted by SGS are about half of the ranges predicted by IHS and are consistent across all the project cases for both 2003 and 2005 forecasts.
6. The economic indicators predicted by the SGS method for a typical project are log-normally distributed and are similar to the probability distributions exhibited by the BS method. The log-normal distribution form is used to determine the mean or "P50" values for the IHS method.

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APPENDIX A

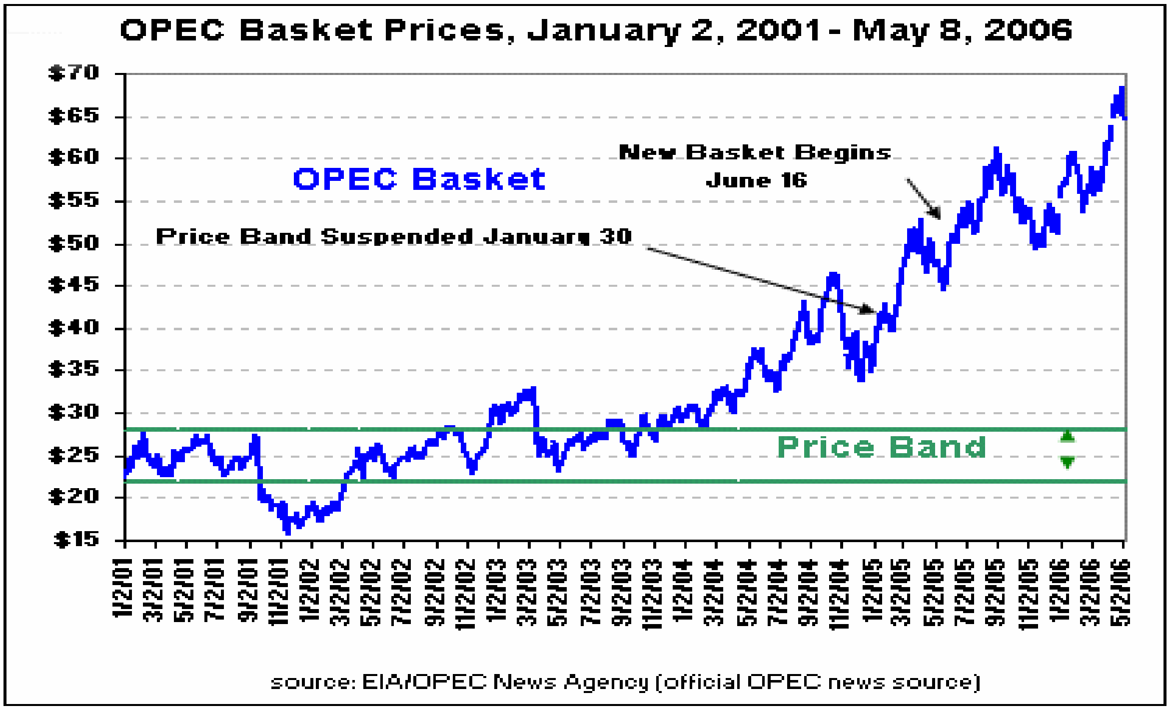

Fig. A-1 - OPEC basket prices from January 2001 through May 2006 (http://www.eia.doe.gov/emeu/cabs/opec.html)[15]

APPENDIX B

Table B-1 Economic parameters

	Investment, $	Gas Offset, $/mcf	Incremental Op Costs, $/month	Incremental Handling Costs, $/bbl	Oil Incremental Handling Costs, $/bbl	Water Incremental Handling Costs, $/bbl	Revenue Interest	Income Tax Rate
CASE-1	300,000	0.45	3,000	0.01671	0	0	0.125	0.35
CASE-2	140,000	0.75	3,000	2.5	0	0	0.125	0.35
CASE-3	80,000	0.65	-	0.03	0	0	0.125	0.35
CASE-4	70,000	0.65	-	0.03	0	0	0.125	0.35
CASE-5	200,000	0.65	-	0.03	0	0	0.125	0.35
CASE-6	45,000	0	1,500	0.0167	0	0	0.25	0.35
CASE-7	180,000	0.75	1,500	0.0167	0	0	0.25	0.35
CASE-8	55,000	0.75	1,500	0.0167	0	0	0.25	0.35
CASE-9	3,752,000	0	900	0.025	0.12	0.1	0.19	0.35
CASE-10	3,600,000	0	4,000	0	0	0	0.125	0.35
CASE-11	250,000	0	3,000	0	0	0	0.14	0.35
CASE-12	18,000,000	0	98,250	0.005	0.16	0	0.125	0.35
CASE-13	3,000,000	0.75	3,300	0	0	0	0.3	0.35
CASE-14	2,000,000	0.75	3,300	0	0	0	0.2	0.35
CASE-15	5,000,000	0.75	35,000	0	0	0	0.2	0.35
CASE-16	4,000,000	0	8,000	0	0	0	0.1667	0.35
CASE-17	2,500,000	0	7,500	0	0	0	0.1667	0.35
CASE-18	700,000	0	2,500	0.1	0	0	0.125	0.35
CASE-19	3,000,000	0	10,000	0	0	0	0.1667	0.35
CASE-20	3,000,000	0	10,000	0.035	0	0	0.1667	0.35
CASE-21	2,867,551	0	3,000	0	0	0	0.1667	0.35
CASE-22	1,169,000	0.75	-	3.1	0	0	0.1667	0.35
CASE-23	1,160,000	0.75	-	4.17	0	0	0.125	0.35
CASE-24	10,000	0.75	50	0.0167	0	0	0.125	0.35
CASE-25	10,000	0.75	50	0.0167	0	0	0.125	0.35
CASE-26	10,000	0.75	16	0.0167	0	0	0.125	0.35

APPENDIX B (CONTINUED)

Table B-2 Historical oil price and consumer price index

	Historical WTI Oil Prices		CPI Index	Inflation Index		Adjusted Oil Price	Deflated Oil Price
	Month	Nominal $		Nov'04=1.0	1974=1.0	Nov04 $	1974=6.95
1	Jan-74	6.95	46.6	0.2440	1.0000	28.49	6.95
2	Feb-74	6.87	47.2	0.2471	1.0129	27.80	6.78
3	Mar-74	6.77	47.8	0.2503	1.0258	27.05	6.60
4	Apr-74	6.77	48.0	0.2513	1.0300	26.94	6.57
5	May-74	6.87	48.6	0.2545	`1.0429	27.00	6.59
6	Jun-74	6.85	49.0	0.2565	1.0515	26.70	6.51
7	Jul-74	6.80	49.4	0.2586	1.0601	26.29	6.41
8	Aug-74	6.71	50.0	0.2618	1.0730	25.63	6.25
9	Sep-74	6.70	50.6	0.2649	1.0858	25.29	6.17
10	Oct-74	6.97	51.1	0.2675	1.0966	26.05	6.36
11	Nov-74	6.97	51.5	0.2696	1.1052	25.85	6.31
12	Dec-74	7.09	51.9	0.2717	1.1137	26.09	6.37
13	Jan-75	7.61	52.1	0.2728	1.1180	27.90	6.81
14	Feb-75	7.47	52.5	0.2749	1.1266	27.18	6.63
15	Mar-75	7.57	52.7	0.2759	1.1309	27.44	6.69
16	Apr-75	7.55	52.9	0.2770	1.1352	27.26	6.65
17	May-75	7.52	53.2	0.2785	1.1416	27.00	6.59
18	Jun-75	7.49	53.6	0.2806	1.1502	26.69	6.51
19	Jul-75	7.75	54.2	0.2838	1.1631	27.31	6.66
20	Aug-75	7.73	54.3	0.2843	1.1652	27.19	6.63
21	Sep-75	7.75	54.6	0.2859	1.1717	27.11	6.61
22	Oct-75	7.83	54.9	0.2874	1.1781	27.24	6.65
23	Nov-75	7.80	55.3	0.2895	1.1867	26.94	6.57
24	Dec-75	7.93	55.5	0.2906	1.1910	27.29	6.66
25	Jan-76	8.63	55.6	0.2911	1.1931	29.65	7.23
26	Feb-76	7.87	55.8	0.2921	1.1974	26.94	6.57
27	Mar-76	7.79	55.9	0.2927	1.1996	26.62	6.49
28	Apr-76	7.86	56.1	0.2937	1.2039	26.76	6.53
29	May-76	7.89	56.5	0.2958	1.2124	26.67	6.51
30	Jun-76	7.99	56.8	0.2974	1.2189	26.87	6.56
31	Jul-76	8.04	57.1	0.2990	1.2253	26.89	6.56
32	Aug-76	8.03	57.4	0.3005	1.2318	26.72	6.52
33	Sep-76	8.39	57.6	0.3016	1.2361	27.82	6.79
34	Oct-76	8.46	57.9	0.3031	1.2425	27.91	6.81
35	Nov-76	8.62	58.0	0.3037	1.2446	28.39	6.93
36	Dec-76	8.62	58.2	0.3047	1.2489	28.29	6.90
37	Jan-77	8.50	58.5	0.3063	1.2554	27.75	6.77

38	Feb-77	8.57	59.1	0.3094	1.2682	27.70	6.76
39	Mar-77	8.45	59.5	0.3115	1.2768	27.13	6.62
40	Apr-77	8.40	60.0	0.3141	1.2876	26.74	6.52
41	May-77	8.49	60.3	0.3157	1.2940	26.89	6.56
42	Jun-77	8.44	60.7	0.3178	1.3026	26.56	6.48
43	Jul-77	8.48	61.0	0.3194	1.3090	26.55	6.48
44	Aug-77	8.62	61.2	0.3204	1.3133	26.90	6.56
45	Sep-77	8.63	61.4	0.3215	1.3176	26.85	6.55
46	Oct-77	8.72	61.6	0.3225	1.3219	27.04	6.60
47	Nov-77	8.72	61.9	0.3241	1.3283	26.91	6.56
48	Dec-77	8.77	62.1	0.3251	1.3326	26.97	6.58
49	Jan-78	8.68	62.5	0.3272	1.3412	26.53	6.47
50	Feb-78	8.84	62.9	0.3293	1.3498	26.84	6.55
51	Mar-78	8.80	63.4	0.3319	1.3605	26.51	6.47
52	Apr-78	8.82	63.9	0.3346	1.3712	26.36	6.43
53	May-78	8.81	64.5	0.3377	1.3841	26.09	6.37
54	Jun-78	9.05	65.2	0.3414	1.3991	26.51	6.47
55	Jul-78	8.96	65.7	0.3440	1.4099	26.05	6.36
56	Aug-78	9.05	66.0	0.3455	1.4163	26.19	6.39
57	Sep-78	9.15	66.5	0.3482	1.4270	26.28	6.41
58	Oct-78	9.17	67.1	0.3513	1.4399	26.10	6.37
59	Nov-78	9.20	67.4	0.3529	1.4464	26.07	6.36
60	Dec-78	9.47	67.7	0.3545	1.4528	26.72	6.52
61	Jan-79	9.46	68.3	0.3576	1.4657	26.45	6.45
62	Feb-79	9.69	69.1	0.3618	1.4828	26.78	6.53
63	Mar-79	9.83	69.8	0.3654	1.4979	26.90	6.56
64	Apr-79	10.33	70.6	0.3696	1.5150	27.95	6.82
65	May-79	10.71	71.5	0.3743	1.5343	28.61	6.98
66	Jun-79	11.70	72.3	0.3785	1.5515	30.91	7.54
67	Jul-79	13.39	73.1	0.3827	1.5687	34.99	8.54
68	Aug-79	14.00	73.8	0.3864	1.5837	36.23	8.84
69	Sep-79	14.57	74.6	0.3906	1.6009	37.30	9.10
70	Oct-79	15.11	75.2	0.3937	1.6137	38.38	9.36
71	Nov-79	15.52	75.9	0.3974	1.6288	39.06	9.53
72	Dec-79	17.03	76.7	0.4016	1.6459	42.41	10.35
73	Jan-80	17.86	77.8	0.4073	1.6695	43.85	10.70
74	Feb-80	18.81	78.9	0.4131	1.6931	45.53	11.11
75	Mar-80	19.34	80.1	0.4194	1.7189	46.12	11.25
76	Apr-80	20.29	81.0	0.4241	1.7382	47.84	11.67
77	May-80	21.01	81.8	0.4283	1.7554	49.06	11.97
78	Jun-80	21.53	82.7	0.4330	1.7747	49.72	12.13
79	Jul-80	22.26	82.7	0.4330	1.7747	51.41	12.54
80	Aug-80	22.63	83.3	0.4361	1.7876	51.89	12.66
81	Sep-80	22.59	84.0	0.4398	1.8026	51.37	12.53
82	Oct-80	23.23	84.8	0.4440	1.8197	52.32	12.77
83	Nov-80	23.92	85.5	0.4476	1.8348	53.44	13.04
84	Dec-80	25.80	86.3	0.4518	1.8519	57.10	13.93

85	Jan-81	28.85	87.0	0.4555	1.8670	63.34	15.45
86	Feb-81	34.14	87.9	0.4602	1.8863	74.18	18.10
87	Mar-81	34.70	88.5	0.4634	1.8991	74.89	18.27
88	Apr-81	34.05	89.1	0.4665	1.9120	72.99	17.81
89	May-81	32.71	89.8	0.4702	1.9270	69.57	16.97
90	Jun-81	31.71	90.6	0.4743	1.9442	66.85	16.31
91	Jul-81	31.13	91.6	0.4796	1.9657	64.91	15.84
92	Aug-81	31.13	92.3	0.4832	1.9807	64.42	15.72
93	Sep-81	31.13	93.2	0.4880	2.0000	63.80	15.57
94	Oct-81	31.00	93.4	0.4890	2.0043	63.39	15.47
95	Nov-81	30.98	93.7	0.4906	2.0107	63.15	15.41
96	Dec-81	30.72	94.0	0.4921	2.0172	62.42	15.23
97	Jan-82	33.85	94.3	0.4937	2.0236	68.56	16.73
98	Feb-82	31.56	94.6	0.4953	2.0300	63.72	15.55
99	Mar-82	28.48	94.5	0.4948	2.0279	57.56	14.04
100	Apr-82	33.45	94.9	0.4969	2.0365	67.32	16.43
101	May-82	35.93	95.8	0.5016	2.0558	71.63	17.48
102	Jun-82	35.07	97.0	0.5079	2.0815	69.06	16.85
103	Jul-82	34.16	97.5	0.5105	2.0923	66.92	16.33
104	Aug-82	33.95	97.7	0.5115	2.0966	66.37	16.19
105	Sep-82	35.63	97.9	0.5126	2.1009	69.51	16.96
106	Oct-82	35.68	98.2	0.5141	2.1073	69.40	16.93
107	Nov-82	34.15	98.0	0.5131	2.1030	66.56	16.24
108	Dec-82	31.70	97.6	0.5110	2.0944	62.04	15.14
109	Jan-83	31.19	97.8	0.5120	2.0987	60.91	14.86
110	Feb-83	28.95	97.9	0.5126	2.1009	56.48	13.78
111	Mar-83	28.62	97.9	0.5126	2.1009	55.84	13.62
112	Apr-83	30.61	98.6	0.5162	2.1159	59.30	14.47
113	May-83	30.00	99.2	0.5194	2.1288	57.76	14.09
114	Jun-83	31.00	99.5	0.5209	2.1352	59.51	14.52
115	Jul-83	31.66	99.9	0.5230	2.1438	60.53	14.77
116	Aug-83	31.91	100.2	0.5246	2.1502	60.83	14.84
117	Sep-83	31.11	100.7	0.5272	2.1609	59.01	14.40
118	Oct-83	30.41	101.0	0.5288	2.1674	57.51	14.03
119	Nov-83	29.84	101.2	0.5298	2.1717	56.32	13.74
120	Dec-83	29.24	101.3	0.5304	2.1738	55.13	13.45
121	Jan-84	29.74	101.9	0.5335	2.1867	55.74	13.60
122	Feb-84	30.20	102.4	0.5361	2.1974	56.33	13.74
123	Mar-84	30.76	102.6	0.5372	2.2017	57.26	13.97
124	Apr-84	30.60	103.1	0.5398	2.2124	56.69	13.83
125	May-84	30.67	103.4	0.5414	2.2189	56.65	13.82
126	Jun-84	29.86	103.7	0.5429	2.2253	55.00	13.42
127	Jul-84	28.71	104.1	0.5450	2.2339	52.68	12.85
128	Aug-84	29.22	104.5	0.5471	2.2425	53.41	13.03
129	Sep-84	29.38	105.0	0.5497	2.2532	53.44	13.04
130	Oct-84	28.58	105.3	0.5513	2.2597	51.84	12.65
131	Nov-84	27.99	105.3	0.5513	2.2597	50.77	12.39

132	Dec-84	26.65	105.3	0.5513	2.2597	48.34	11.79
133	Jan-85	25.85	105.5	0.5524	2.2639	46.80	11.42
134	Feb-85	27.33	106.0	0.5550	2.2747	49.25	12.01
135	Mar-85	28.53	106.4	0.5571	2.2833	51.21	12.50
136	Apr-85	28.60	106.9	0.5597	2.2940	51.10	12.47
137	May-85	27.61	107.3	0.5618	2.3026	49.15	11.99
138	Jun-85	27.14	107.6	0.5634	2.3090	48.18	11.75
139	Jul-85	27.23	107.8	0.5644	2.3133	48.25	11.77
140	Aug-85	27.58	108.0	0.5654	2.3176	48.78	11.90
141	Sep-85	28.53	108.3	0.5670	2.3240	50.32	12.28
142	Oct-85	29.54	108.7	0.5691	2.3326	51.91	12.66
143	Nov-85	30.90	109.0	0.5707	2.3391	54.15	13.21
144	Dec-85	27.46	109.3	0.5723	2.3455	47.99	11.71
145	Jan-86	22.93	109.6	0.5738	2.3519	39.96	9.75
146	Feb-86	15.45	109.3	0.5723	2.3455	27.01	6.59
147	Mar-86	12.61	108.8	0.5696	2.3348	22.14	5.40
148	Apr-86	12.84	108.6	0.5686	2.3305	22.59	5.51
149	May-86	15.38	108.9	0.5702	2.3369	26.97	6.58
150	Jun-86	13.43	109.5	0.5733	2.3498	23.42	5.71
151	Jul-86	11.58	109.5	0.5733	2.3498	20.21	4.93
152	Aug-86	15.10	109.7	0.5743	2.3541	26.28	6.41
153	Sep-86	14.87	110.2	0.5770	2.3648	25.77	6.29
154	Oct-86	14.90	110.3	0.5775	2.3670	25.80	6.29
155	Nov-86	15.22	110.4	0.5780	2.3691	26.33	6.43
156	Dec-86	16.11	110.5	0.5785	2.3712	27.84	6.79
157	Jan-87	18.65	111.2	0.5822	2.3863	32.04	7.82
158	Feb-87	17.75	111.6	0.5843	2.3948	30.38	7.41
159	Mar-87	18.30	112.1	0.5869	2.4056	31.19	7.61
160	Apr-87	18.68	112.7	0.5901	2.4185	31.65	7.72
161	May-87	19.44	113.1	0.5921	2.4270	32.83	8.01
162	Jun-87	20.07	113.5	0.5942	2.4356	33.78	8.24
163	Jul-87	21.34	113.8	0.5958	2.4421	35.82	8.74
164	Aug-87	20.31	114.4	0.5990	2.4549	33.91	8.27
165	Sep-87	19.53	115.0	0.6021	2.4678	32.44	7.91
166	Oct-87	19.86	115.3	0.6037	2.4742	32.90	8.03
167	Nov-87	18.85	115.4	0.6042	2.4764	31.21	7.61
168	Dec-87	17.27	115.4	0.6042	2.4764	28.59	6.98
169	Jan-88	17.13	115.7	0.6058	2.4828	28.28	6.90
170	Feb-88	16.80	116.0	0.6073	2.4893	27.66	6.75
171	Mar-88	16.20	116.5	0.6099	2.5000	26.56	6.48
172	Apr-88	17.86	117.1	0.6131	2.5129	29.14	7.11
173	May-88	17.42	117.5	0.6152	2.5215	28.32	6.91
174	Jun-88	16.53	118.0	0.6178	2.5322	26.75	6.53
175	Jul-88	15.50	118.5	0.6204	2.5429	24.98	6.09
176	Aug-88	15.52	119.0	0.6230	2.5536	24.92	6.08
177	Sep-88	14.54	119.8	0.6272	2.5708	23.17	5.65
178	Oct-88	13.77	120.2	0.6293	2.5794	21.88	5.34

179	Nov-88	14.14	120.3	0.6298	2.5815	22.45	5.48
180	Dec-88	16.38	120.5	0.6309	2.5858	25.97	6.34
181	Jan-89	18.02	121.1	0.6340	2.5987	28.43	6.94
182	Feb-89	17.94	121.6	0.6366	2.6094	28.17	6.87
183	Mar-89	19.48	122.3	0.6403	2.6245	30.43	7.42
184	Apr-89	21.07	123.1	0.6445	2.6416	32.69	7.98
185	May-89	20.12	123.8	0.6482	2.6567	31.05	7.57
186	Jun-89	20.05	124.1	0.6497	2.6631	30.86	7.53
187	Jul-89	19.78	124.4	0.6513	2.6695	30.37	7.41
188	Aug-89	18.58	124.6	0.6524	2.6738	28.48	6.95
189	Sep-89	19.59	125.0	0.6545	2.6824	29.94	7.30
190	Oct-89	20.10	125.6	0.6576	2.6953	30.56	7.46
191	Nov-89	19.86	125.9	0.6592	2.7017	30.12	7.35
192	Dec-89	21.10	126.1	0.6602	2.7060	31.96	7.80
193	Jan-90	22.86	127.4	0.6670	2.7339	34.28	8.36
194	Feb-90	22.11	128.0	0.6702	2.7468	33.00	8.05
195	Mar-90	20.39	128.7	0.6738	2.7618	30.26	7.38
196	Apr-90	18.43	128.9	0.6749	2.7661	27.30	6.66
197	May-90	18.20	129.2	0.6764	2.7725	26.90	6.56
198	Jun-90	16.70	129.9	0.6801	2.7876	24.55	5.99
199	Jul-90	18.45	130.4	0.6827	2.7983	27.03	6.59
200	Aug-90	27.31	131.6	0.6890	2.8240	39.63	9.67
201	Sep-90	33.51	132.7	0.6948	2.8476	48.23	11.77
202	Oct-90	36.04	133.5	0.6990	2.8648	51.56	12.58
203	Nov-90	32.33	133.8	0.7005	2.8712	46.15	11.26
204	Dec-90	27.28	133.8	0.7005	2.8712	38.94	9.50
205	Jan-91	25.23	134.6	0.7047	2.8884	35.80	8.73
206	Feb-91	20.48	134.8	0.7058	2.8927	29.01	7.08
207	Mar-91	19.90	135.0	0.7068	2.8970	28.15	6.87
208	Apr-91	20.83	135.2	0.7079	2.9013	29.43	7.18
209	May-91	21.23	135.6	0.7099	2.9099	29.90	7.30
210	Jun-91	20.19	136.0	0.7120	2.9185	28.35	6.92
211	Jul-91	21.40	136.2	0.7131	2.9227	30.01	7.32
212	Aug-91	21.69	136.6	0.7152	2.9313	30.33	7.40
213	Sep-91	21.89	137.2	0.7183	2.9442	30.47	7.43
214	Oct-91	23.23	137.4	0.7194	2.9485	32.29	7.88
215	Nov-91	22.46	137.8	0.7215	2.9571	31.13	7.60
216	Dec-91	19.50	137.9	0.7220	2.9592	27.01	6.59
217	Jan-92	18.79	138.1	0.7230	2.9635	25.98	6.34
218	Feb-92	19.01	138.6	0.7257	2.9742	26.20	6.39
219	Mar-92	18.92	139.3	0.7293	2.9893	25.94	6.33
220	Apr-92	20.23	139.5	0.7304	2.9936	27.70	6.76
221	May-92	20.98	139.7	0.7314	2.9979	28.68	7.00
222	Jun-92	22.38	140.2	0.7340	3.0086	30.49	7.44
223	Jul-92	21.77	140.5	0.7356	3.0150	29.59	7.22
224	Aug-92	21.34	140.9	0.7377	3.0236	28.93	7.06
225	Sep-92	21.88	141.3	0.7398	3.0322	29.58	7.22

226	Oct-92	21.69	141.8	0.7424	3.0429	29.22	7.13
227	Nov-92	20.34	142.0	0.7435	3.0472	27.36	6.67
228	Dec-92	19.41	141.9	0.7429	3.0451	26.13	6.37
229	Jan-93	19.03	142.6	0.7466	3.0601	25.49	6.22
230	Feb-93	20.09	143.1	0.7492	3.0708	26.81	6.54
231	Mar-93	20.32	143.6	0.7518	3.0815	27.03	6.59
232	Apr-93	20.25	144.0	0.7539	3.0901	26.86	6.55
233	May-93	19.95	144.2	0.7550	3.0944	26.42	6.45
234	Jun-93	19.09	144.4	0.7560	3.0987	25.25	6.16
235	Jul-93	17.89	144.4	0.7560	3.0987	23.66	5.77
236	Aug-93	18.01	144.8	0.7581	3.1073	23.76	5.80
237	Sep-93	18.09	145.1	0.7597	3.1137	23.81	5.81
238	Oct-93	18.15	145.7	0.7628	3.1266	23.79	5.81
239	Nov-93	16.61	145.8	0.7634	3.1288	21.76	5.31
240	Dec-93	14.51	145.8	0.7634	3.1288	19.01	4.64
241	Jan-94	15.03	146.2	0.7654	3.1373	19.63	4.79
242	Feb-94	14.78	146.7	0.7681	3.1481	19.24	4.69
243	Mar-94	14.68	147.2	0.7707	3.1588	19.05	4.65
244	Apr-94	16.42	147.4	0.7717	3.1631	21.28	5.19
245	May-94	17.89	147.5	0.7723	3.1652	23.17	5.65
246	Jun-94	19.06	148.0	0.7749	3.1760	24.60	6.00
247	Jul-94	19.65	148.4	0.7770	3.1845	25.29	6.17
248	Aug-94	18.38	149.0	0.7801	3.1974	23.56	5.75
249	Sep-94	17.45	149.4	0.7822	3.2060	22.31	5.44
250	Oct-94	17.72	149.5	0.7827	3.2082	22.64	5.52
251	Nov-94	18.07	149.7	0.7838	3.2124	23.06	5.62
252	Dec-94	17.16	149.7	0.7838	3.2124	21.89	5.34
253	Jan-95	18.04	150.3	0.7869	3.2253	22.93	5.59
254	Feb-95	18.57	150.9	0.7901	3.2382	23.50	5.73
255	Mar-95	18.54	151.4	0.7927	3.2489	23.39	5.71
256	Apr-95	19.90	151.9	0.7953	3.2597	25.02	6.10
257	May-95	19.74	152.2	0.7969	3.2661	24.77	6.04
258	Jun-95	18.45	152.5	0.7984	3.2725	23.11	5.64
259	Jul-95	17.33	152.5	0.7984	3.2725	21.71	5.30
260	Aug-95	18.02	152.9	0.8005	3.2811	22.51	5.49
261	Sep-95	18.23	153.2	0.8021	3.2876	22.73	5.55
262	Oct-95	17.43	153.7	0.8047	3.2983	21.66	5.28
263	Nov-95	17.99	153.6	0.8042	3.2961	22.37	5.46
264	Dec-95	19.03	153.5	0.8037	3.2940	23.68	5.78
265	Jan-96	18.85	154.4	0.8084	3.3133	23.32	5.69
266	Feb-96	19.09	154.9	0.8110	3.3240	23.54	5.74
267	Mar-96	21.33	155.7	0.8152	3.3412	26.17	6.38
268	Apr-96	23.50	156.3	0.8183	3.3541	28.72	7.01
269	May-96	21.17	156.6	0.8199	3.3605	25.82	6.30
270	Jun-96	20.42	156.7	0.8204	3.3627	24.89	6.07
271	Jul-96	21.30	157.0	0.8220	3.3691	25.91	6.32
272	Aug-96	21.90	157.3	0.8236	3.3755	26.59	6.49

273	Sep-96	23.97	157.8	0.8262	3.3863	29.01	7.08
274	Oct-96	24.88	158.3	0.8288	3.3970	30.02	7.32
275	Nov-96	23.71	158.6	0.8304	3.4034	28.55	6.97
276	Dec-96	25.22	158.6	0.8304	3.4034	30.37	7.41
277	Jan-97	25.13	159.1	0.8330	3.4142	30.17	7.36
278	Feb-97	22.18	159.6	0.8356	3.4249	26.54	6.48
279	Mar-97	20.97	160.0	0.8377	3.4335	25.03	6.11
280	Apr-97	19.70	160.2	0.8387	3.4378	23.49	5.73
281	May-97	20.82	160.1	0.8382	3.4356	24.84	6.06
282	Jun-97	19.26	160.3	0.8393	3.4399	22.95	5.60
283	Jul-97	19.66	160.5	0.8403	3.4442	23.40	5.71
284	Aug-97	19.95	160.8	0.8419	3.4506	23.70	5.78
285	Sep-97	19.80	161.2	0.8440	3.4592	23.46	5.72
286	Oct-97	21.33	161.6	0.8461	3.4678	25.21	6.15
287	Nov-97	20.19	161.5	0.8455	3.4657	23.88	5.83
288	Dec-97	18.33	161.3	0.8445	3.4614	21.71	5.30
289	Jan-98	16.72	161.6	0.8461	3.4678	19.76	4.82
290	Feb-98	16.06	161.9	0.8476	3.4742	18.95	4.62
291	Mar-98	15.12	162.2	0.8492	3.4807	17.80	4.34
292	Apr-98	15.35	162.5	0.8508	3.4871	18.04	4.40
293	May-98	14.91	162.8	0.8524	3.4936	17.49	4.27
294	Jun-98	13.72	163.0	0.8534	3.4979	16.08	3.92
295	Jul-98	14.17	163.2	0.8545	3.5021	16.58	4.05
296	Aug-98	13.47	163.4	0.8555	3.5064	15.75	3.84
297	Sep-98	15.03	163.6	0.8565	3.5107	17.55	4.28
298	Oct-98	14.46	164.0	0.8586	3.5193	16.84	4.11
299	Nov-98	13.00	164.0	0.8586	3.5193	15.14	3.69
300	Dec-98	11.35	163.9	0.8581	3.5172	13.23	3.23
301	Jan-99	12.51	164.3	0.8602	3.5258	14.54	3.55
302	Feb-99	12.01	164.5	0.8613	3.5300	13.94	3.40
303	Mar-99	14.68	165.0	0.8639	3.5408	16.99	4.15
304	Apr-99	17.31	166.2	0.8702	3.5665	19.89	4.85
305	May-99	17.72	166.2	0.8702	3.5665	20.36	4.97
306	Jun-99	17.92	166.2	0.8702	3.5665	20.59	5.02
307	Jul-99	20.10	166.7	0.8728	3.5773	23.03	5.62
308	Aug-99	21.28	167.1	0.8749	3.5858	24.32	5.93
309	Sep-99	23.80	167.9	0.8791	3.6030	27.07	6.61
310	Oct-99	23.80	168.2	0.8806	3.6094	27.03	6.59
311	Nov-99	25.00	168.3	0.8812	3.6116	28.37	6.92
312	Dec-99	26.10	168.3	0.8812	3.6116	29.62	7.23
313	Jan-00	27.26	168.8	0.8838	3.6223	30.85	7.53
314	Feb-00	29.36	169.8	0.8890	3.6438	33.03	8.06
315	Mar-00	29.84	171.2	0.8963	3.6738	33.29	8.12
316	Apr-00	25.72	171.3	0.8969	3.6760	28.68	7.00
317	May-00	28.79	171.5	0.8979	3.6803	32.06	7.82
318	Jun-00	31.82	172.4	0.9026	3.6996	35.25	8.60
319	Jul-00	29.70	172.8	0.9047	3.7082	32.83	8.01

320	Aug-00	31.26	172.8	0.9047	3.7082	34.55	8.43
321	Sep-00	33.88	173.7	0.9094	3.7275	37.25	9.09
322	Oct-00	33.11	174.0	0.9110	3.7339	36.34	8.87
323	Nov-00	34.42	174.1	0.9115	3.7361	37.76	9.21
324	Dec-00	28.44	174.0	0.9110	3.7339	31.22	7.62
325	Jan-01	29.59	175.1	0.9168	3.7575	32.28	7.87
326	Feb-01	29.61	175.8	0.9204	3.7725	32.17	7.85
327	Mar-01	27.24	176.2	0.9225	3.7811	29.53	7.20
328	Apr-01	27.49	176.9	0.9262	3.7961	29.68	7.24
329	May-01	28.63	177.7	0.9304	3.8133	30.77	7.51
330	Jun-01	27.64	178.0	0.9319	3.8197	29.66	7.24
331	Jul-01	26.42	177.5	0.9293	3.8090	28.43	6.94
332	Aug-01	27.36	177.5	0.9293	3.8090	29.44	7.18
333	Sep-01	26.21	178.3	0.9335	3.8262	28.08	6.85
334	Oct-01	22.18	177.7	0.9304	3.8133	23.84	5.82
335	Nov-01	19.80	177.4	0.9288	3.8069	21.32	5.20
336	Dec-01	19.39	176.7	0.9251	3.7918	20.96	5.11
337	Jan-02	19.71	177.1	0.9272	3.8004	21.26	5.19
338	Feb-02	20.72	177.8	0.9309	3.8155	22.26	5.43
339	Mar-02	24.53	178.8	0.9361	3.8369	26.20	6.39
340	Apr-02	26.18	179.8	0.9414	3.8584	27.81	6.79
341	May-02	27.04	179.8	0.9414	3.8584	28.72	7.01
342	Jun-02	25.52	179.9	0.9419	3.8605	27.09	6.61
343	Jul-02	26.97	180.1	0.9429	3.8648	28.60	6.98
344	Aug-02	28.39	180.7	0.9461	3.8777	30.01	7.32
345	Sep-02	29.66	181.0	0.9476	3.8841	31.30	7.64
346	Oct-02	28.84	181.3	0.9492	3.8906	30.38	7.41
347	Nov-02	26.35	181.3	0.9492	3.8906	27.76	6.77
348	Dec-02	29.46	180.9	0.9471	3.8820	31.10	7.59
349	Jan-03	32.95	181.7	0.9513	3.8991	34.63	8.45
350	Feb-03	35.83	183.1	0.9586	3.9292	37.37	9.12
351	Mar-03	33.51	184.2	0.9644	3.9528	34.75	8.48
352	Apr-03	28.17	183.8	0.9623	3.9442	29.27	7.14
353	May-03	28.11	183.5	0.9607	3.9378	29.26	7.14
354	Jun-03	30.66	183.7	0.9618	3.9421	31.88	7.78
355	Jul-03	30.75	183.9	0.9628	3.9464	31.94	7.79
356	Aug-03	31.57	184.6	0.9665	3.9614	32.67	7.97
357	Sep-03	28.31	185.2	0.9696	3.9742	29.20	7.12
358	Oct-03	30.34	185.0	0.9686	3.9700	31.32	7.64
359	Nov-03	31.11	184.5	0.9660	3.9592	32.20	7.86
360	Dec-03	32.13	184.3	0.9649	3.9549	33.30	8.12
361	Jan-04	34.31	185.2	0.9696	3.9742	35.38	8.63
362	Feb-04	34.68	186.2	0.9749	3.9957	35.58	8.68
363	Mar-04	36.74	187.4	0.9812	4.0215	37.45	9.14
364	Apr-04	36.75	188.0	0.9843	4.0343	37.34	9.11
365	May-04	40.28	189.1	0.9901	4.0579	40.68	9.92
366	Jun-04	38.03	189.7	0.9932	4.0708	38.29	9.34

367	Jul-04	40.78	189.4	0.9916	4.0644	41.12	10.03
368	Aug-04	44.90	189.5	0.9921	4.0665	45.26	11.04
369	Sep-04	45.94	189.9	0.9942	4.0751	46.20	11.27
370	Oct-04	53.28	190.9	0.9995	4.0966	53.31	13.01
371	Nov-04	48.47	191.0	1.0000	4.0987	48.47	11.83

APPENDIX C

VBA CODE FOR BOOTSTRAP METHOD

```
Option Explicit
Dim SumData As Long
Dim nGener As Integer
Dim Data As Range

Function FindRandom(ByVal LowerB As Integer, ByVal UpperB As Long, _
            ByVal Data As Variant) As Variant
Dim TestVar As Long
Do
  TestVar = CLng(Rnd * (1.1 * UpperB))
  If TestVar >= LowerB And TestVar <= UpperB Then
    FindRandom = Data(TestVar)
    Exit Function
   End If
Loop
End Function

Sub CalcNumData()
Dim i As Long
With Sheets("Data")
For i = 1 To 120000000
  If .Range("B" & i) = "" Then
  SumData = i - 2
  Set Data = .Range("B2:B" & SumData + 1)
```

```
  Exit Sub
  End If
Next
End With
End Sub

Sub GenerateData()
Dim i As Long
Dim j As Byte
Sheets("MPC").Select
CalcNumData

With Sheets("MPC")
  nGener = .Range("NGENER")
  If nGener > 255 Or nGener <= 0 Then
     MsgBox "pls correct the ngener !", vbCritical, "Error"
     Exit Sub
  End If
  .Range("A2:IV65536").ClearContents

  For i = 1 To Data.Count
    .Cells(i + 2, 1) = i
  Next

  For j = 1 To nGener
    .Cells(2, 1 + j) = "G - " & j
    For i = 1 To Data.Count
      .Cells(i + 2, 1 + j) = FindRandom(1, Data.Count, Data)
```

```
    Next
  Next
End With
End Sub

Sub RunProgram()
Dim i As Long, j As Long
Dim cmpc As Range, forecast As Range
With Sheets("MPC")
For j = 1 To 2000
   If .Cells(2, 1 + j) = "" Then Exit Sub

   For i = 1 To 120
      Sheets("program").Range("C" & 8 + i) = .Cells(2 + i, 1 + j)
   Next

   ' capture into different columns
   Set cmpc = Range("CMPC"): Set forecast = Range("FORECAST")
         Sheets("CMPC").Cells(2, 1 + j) = "SAMPLE-" & j
      Sheets("FORECAST").Cells(2, 1 + j) = "SAMPLE-" & j

   For i = 1 To 120
      Sheets("CMPC").Cells(i + 2, 1 + j) = cmpc(i, 1)
      Sheets("FORECAST").Cells(i + 2, 1 + j) = forecast(i, 1)
   Next
Next
End With
End Sub
```

VBA CODE FOR ECONOMIC EVALUATIONS

```
Option Explicit

'Economic Model Calculations

Sub RunSummary()
Dim i As Long, j As Long, k As Long, m As Long, n As Long, NPVV As Range
Dim Sum As Long, Count As Long, Number As Long

Set NPVV = Range("NPVV")

With Sheets("Production")
For j = 1 To 26

  Sum = 0
  Sum = Sum + j

  'Set the case number

  Sheets("Run_model").Cells(2, 14) = Sum

     'Economic parameters

     Sheets("Run_model").Cells(5, 22) = .Cells(5, 84 + j)
     Sheets("Run_model").Cells(6, 22) = .Cells(6, 84 + j)
     Sheets("Run_model").Cells(7, 22) = .Cells(7, 84 + j)
     Sheets("Run_model").Cells(8, 22) = .Cells(8, 84 + j)
```

```
Sheets("Run_model").Cells(9, 22) = .Cells(9, 84 + j)
Sheets("Run_model").Cells(10, 22) = .Cells(10, 84 + j)
Sheets("Run_model").Cells(11, 22) = .Cells(11, 84 + j)
Sheets("Run_model").Cells(12, 22) = .Cells(12, 84 + j)
Sheets("Run_model").Cells(13, 22) = .Cells(13, 84 + j)
Sheets("Run_model").Cells(14, 22) = .Cells(14, 84 + j)
Sheets("Run_model").Cells(15, 22) = .Cells(15, 84 + j)
Sheets("Run_model").Cells(16, 22) = .Cells(16, 84 + j)
Sheets("Run_model").Cells(17, 22) = .Cells(17, 84 + j)

 'Production Rates
For i = 1 To 120
    Sheets("Run_model").Range("C" & 10 + i) = .Cells(10 + i, 1 + j)
    Sheets("Run_model").Range("D" & 10 + i) = .Cells(10 + i, 28 + j)
    Sheets("Run_model").Range("E" & 10 + i) = .Cells(10 + i, 55 + j)
Next

With Sheets("Oilprice")

    'Bootstrap Method

        'Show model
         Sheets("Run_model").Cells(2, 16) = "Bootstrap"

        'Number of Realizations
         For k = 1 To 2000
             If .Cells(2, 1 + k) = "" Then Exit For
```

```
Count = 0
Count = Count + k

'Set the case number
Sheets("Run_model").Cells(2, 18) = Count

For m = 1 To 120
Sheets("Run_model").Range("B" & 10 + m) = .Cells(2 + m, 1 + k)
Next

' Capture result into summary sheet
Sheets("summary").Cells(k + 4, 1) = "sample- " & k

Sheets("summary").Cells(k + 4, 1 + j) = Range("IRR")
Sheets("summary").Cells(k + 4, 28 + j) = NPVV(1, 1)
Sheets("summary").Cells(k + 4, 55 + j) = NPVV(1, 2)
Sheets("summary").Cells(k + 4, 82 + j) = NPVV(1, 3)
Sheets("summary").Cells(k + 4, 109 + j) = NPVV(2, 1)
Sheets("summary").Cells(k + 4, 136 + j) = NPVV(2, 2)
Sheets("summary").Cells(k + 4, 163 + j) = NPVV(2, 3)

Next

'Sequential Gaussian Simulation Method

'Show model
Sheets("Run_model").Cells(2, 16) = "Gaussian"
```

```
'Number of Realizations
 For k = 1 To 1000
     If .Cells(127, 1 + k) = "" Then Exit For

     Count = 0
     Count = Count + k

     'Set the case number
     Sheets("Run_model").Cells(2, 18) = Count

     For m = 1 To 120
     Sheets("Run_model").Range("B" & 10 + m) = .Cells(127 + m, 1 + k)
     Next

 ' Capture result into summary sheet
 Sheets("summary").Cells(k + 210, 1) = "sample- " & k

 Sheets("summary").Cells(k + 210, 1 + j) = Range("IRR")
 Sheets("summary").Cells(k + 210, 28 + j) = NPVV(1, 1)
 Sheets("summary").Cells(k + 210, 55 + j) = NPVV(1, 2)
 Sheets("summary").Cells(k + 210, 82 + j) = NPVV(1, 3)
 Sheets("summary").Cells(k + 210, 109 + j) = NPVV(2, 1)
 Sheets("summary").Cells(k + 210, 136 + j) = NPVV(2, 2)
 Sheets("summary").Cells(k + 210, 163 + j) = NPVV(2, 3)

 Next

'Historical Method
```

```
'Show model
Sheets("Run_model").Cells(2, 16) = "Historical"

'Number of Realizations
 For k = 1 To 500
     If .Cells(251, 1 + k) = "" Then Exit For

     Count = 0
     Count = Count + k

     'Set the case number
     Sheets("Run_model").Cells(2, 18) = Count

     For m = 1 To 120
     Sheets("Run_model").Range("B" & 10 + m) = .Cells(251 + m, 1 + k)
     Next

 ' Capture result into summary sheet
 Sheets("summary").Cells(k + 276, 1) = "sample-" & k

 Sheets("summary").Cells(k + 276, 1 + j) = Range("IRR")
 Sheets("summary").Cells(k + 276, 28 + j) = NPVV(1, 1)
 Sheets("summary").Cells(k + 276, 55 + j) = NPVV(1, 2)
 Sheets("summary").Cells(k + 276, 82 + j) = NPVV(1, 3)
 Sheets("summary").Cells(k + 276, 109 + j) = NPVV(2, 1)
 Sheets("summary").Cells(k + 276, 136 + j) = NPVV(2, 2)
 Sheets("summary").Cells(k + 276, 163 + j) = NPVV(2, 3)
```

```
   Next

'Inverted Hockey Stick Method

  'Show model
  Sheets("Run_model").Cells(2, 16) = "Inverted HS"

  'Number of Realizations
   For k = 1 To 100
      If .Cells(375, 1 + k) = "" Then Exit For

      Count = 0
      Count = Count + k

      'Set the case number
      Sheets("Run_model").Cells(2, 18) = Count

      For m = 1 To 120
      Sheets("Run_model").Range("B" & 10 + m) = .Cells(375 + m, 1 + k)
      Next

   ' Capture result into summary sheet
   Sheets("summary").Cells(k + 313, 1) = "sample- " & k

   Sheets("summary").Cells(k + 313, 1 + j) = Range("IRR")
   Sheets("summary").Cells(k + 313, 28 + j) = NPVV(1, 1)
   Sheets("summary").Cells(k + 313, 55 + j) = NPVV(1, 2)
```

```
  Sheets("summary").Cells(k + 313, 82 + j) = NPVV(1, 3)
  Sheets("summary").Cells(k + 313, 109 + j) = NPVV(2, 1)
  Sheets("summary").Cells(k + 313, 136 + j) = NPVV(2, 2)
  Sheets("summary").Cells(k + 313, 163 + j) = NPVV(2, 3)

  Next

'Conventional Hockey Stick Method

 'Show model
 Sheets("Run_model").Cells(2, 16) = "Conventional"

 'Number of Realizations
  For k = 1 To 100
      If .Cells(499, 1 + k) = "" Then Exit For

      Count = 0
      Count = Count + k

      'Set the case number
      Sheets("Run_model").Cells(2, 18) = Count

      For m = 1 To 120
      Sheets("Run_model").Range("B" & 10 + m) = .Cells(499 + m, 1 + k)
      Next

  ' Capture result into summary sheet
  Sheets("summary").Cells(k + 322, 1) = "sample- " & k
```

```
            Sheets("summary").Cells(k + 322, 1 + j) = Range("IRR")
            Sheets("summary").Cells(k + 322, 28 + j) = NPVV(1, 1)
            Sheets("summary").Cells(k + 322, 55 + j) = NPVV(1, 2)
            Sheets("summary").Cells(k + 322, 82 + j) = NPVV(1, 3)
            Sheets("summary").Cells(k + 322, 109 + j) = NPVV(2, 1)
            Sheets("summary").Cells(k + 322, 136 + j) = NPVV(2, 2)
            Sheets("summary").Cells(k + 322, 163 + j) = NPVV(2, 3)

            Next

        End With
    Next
    End With

    End Sub
```

VITA

Name:	Festus Lekan Fariyibi
Address:	Texas A&M University Attn: Dr. D.A. McVay Harold Vance Department of Petroleum Engineering 3116 TAMU College Station, TX 77443-3116
Email Address:	festusfariyibi@yahoo.com
Education:	M.S., Petroleum Engineering, 2006 Texas A&M University College Station, Texas
	M.Eng. Petroleum Engineering, 1994 University of Port-Harcourt, Nigeria
	B.Sc., Petroleum Engineering, 1990 University of Ibadan, Nigeria
Work Experience:	Petroleum Engineer, 1997-2004 Chevrontexaco Nigeria SBU Lagos, Nigeria
	Reservoir Engineer, 1993-1997 Shell Petroleum Development Company Port-Harcourt, Nigeria